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The drawing on the cover is of the bark Endeavour, *which, commanded by Captain James Cook and carrying a number of scientific workers, was sent out by the British Admiralty in* 1768 *to chart the South Pacific Ocean and observe the transit of Venus*

ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

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A Memorial to Ernest Rutherford

The achievement of Ernest Rutherford has the monumental simplicity that is characteristic of supreme greatness. To develop the current ideas of one's time, to extend gradually, by informed conjecture and patient endeavour, the boundaries of knowledge, is a service which properly suffices to bring fame and honours to men of science. Rutherford's exploit was of a different kind. He discovered in the exiguous space occupied by the atom a new world, a world of striking complexity which was revealed by marvellously planned and daringly executed exploration, a world which hosts of men of genius are now occupied in investigating. From the time, now nearly fifty years ago, when he first, with Soddy, put forward, and soon convincingly established, the hypothesis that atoms were disintegrating, with the liberation of energy stored somewhere in their recesses, to the day when he saw achieved, as the result of his constant and unswerving prosecution of one directed endeavour, the artificial transmutation of atoms and the subjugation of the nucleus, he was occupied in demolishing accepted ideas and creating a new and unified body of knowledge of supreme significance. He, at the end of his life, might well have said what Horace wrote proudly on the completion of the third book of the Odes: '*Exegi monumentum aere perennius.*' Horace did not contemplate enduring beyond the time when vestal virgins carried out their offices in the Capitol at Rome: Rutherford's name will certainly live as long as our present civilization, and may outlast it.

If, then, an appeal is today sent out by the Royal Society for funds to support a memorial to this great man, it is rather with the desire to pay a pious tribute to his memory than to perpetuate a name so secured and buttressed by his own acts, rather to promote designs which Rutherford would have approved than to approve Rutherford. Rutherford, it is true, was a man whose being was dominated by one great design, that of revealing secrets of atomic structure and atomic change: he possessed to an abnormal degree that power of concentration which Newton expressed in the words 'I keep the subject constantly before me, and wait till the first dawnings open little by little into the full and clear light.' But Rutherford was a much more normal man than Newton, possessed as he was by broad human interests and animated by a kindly heart that rejoiced in contact, and even in amiable dispute, with his fellow men. He was, from his first professorship, the ideal head of a laboratory: he loved to have round him a band of eager young—and not so young—men, to whom he could impart his latest thoughts and projects and communicate his enthusiasm. He would not have been happy, as were Cavendish and, in more recent times, Rayleigh, in solitary research: contact with research students stimulated him just as he stimulated them. Another of his human interests was a deep affection for New Zealand, his homeland, and for the Commonwealth in general. His native town was Nelson, and when he was raised to the peerage he took as his title Baron Rutherford of Nelson. His first professorship was at Montreal, where he passed some of his happiest and most productive years, and while Canada owes to Rutherford a debt which has always been generously acknowledged, Rutherford was always eager to admit that he owed much to Canada. Australia and South Africa also knew his genial influence and won his affection. Young men at work and the countries of the British Commonwealth were, then, dear to Rutherford's heart and an essential part of his life. Such considerations were, no doubt, dominant when the nature of the proposed Rutherford Memorial was deliberated by the Royal Society committee dealing with the matter. Appropriately enough, the chairman of this committee when the appeal went out was Australian-born Professor Oliphant: on his recent departure for his native land he has been succeeded by Sir Henry Tizard, who was an intimate friend of Rutherford and is, like Ulysses, a much experienced man.

The proposal set out in the appeal is that the memorial shall take two main forms, the first being Rutherford Scholarships for post-graduate students within the British Commonwealth, and the second a Rutherford Memorial Lecture, to be delivered at intervals by some leading man of science at selected university centres in the British Commonwealth overseas. Rutherford himself first came to England to work in the inspiring atmosphere of J. J. Thomson's laboratory as the result of the award of an 1851 Exhibition Science Scholarship, and there is no doubt that he would have warmly welcomed any plan, like the present, which will enable young men of proved ability to study here or in some other part of the Commonwealth

—for the proposal envisages that, within the Commonwealth, the holder of a Rutherford Scholarship may work anywhere except at the place of his graduation. Again, the Rutherford Memorial Lecture will enable a leader of science to see, in pleasant circumstances, the work proceeding in some distant university, as Rutherford loved to do, and to encourage young men, who have known him by name only, by his presence and interest. It is difficult to think of any way in which the fellowship of science within the Commonwealth could be more effectively stimulated. A subsidiary proposal is that Rutherford's correspondence, in copy if necessary, shall be collected under the direction of some skilled hand, and, presumably, kept in some centre where it will be readily available to serious students. The desirability of this requires no comment. In the printed appeal nothing is said of a further proposal to arrange for a collected edition, in worthy form, of Rutherford's papers and addresses, but it is believed that this, too, is to be put in hand. Possibly it is considered that the sale of copies will ultimately pay the expenses of publication, but funds will be required in the first instance. Everything that Rutherford wrote is stimulating, and it is to be anticipated that even those familiar with his work will find in such a collected edition, when it appears, many inspiring things that are at present hidden in publications a little apart from the standard periodicals.

It will be admitted on all hands that the proposed memorial scheme has been wisely planned and is deserving of the strongest support from all who have the interests of science and the Commonwealth at heart. The only suggestion that seems appropriate is that a slight extension may be desirable which will, in some manner, include in the scheme admirers of Rutherford outside the Commonwealth. He had many warm friends in the United States. As a young man of thirty he attended a meeting of the American Physical Society, and he wrote 'The meeting was held in Columbia University, where I gave two papers which were pretty well received, as I am the only worker in the field of excited radioactivity in the English-speaking world,' and from that time onward his relations with America were of the warmest. Boltwood was one of his closest friends, and, when the Rutherford correspondence is collected, will be among the most prominent names, but there were many others. 'The English-speaking world,' he wrote: could not the scheme be made to contemplate some occasional gesture to show that he was almost as much at home in the States as in Canada? It is certain that many friends there will respond generously to the appeal: it would be pleasant to think that from time to time a Rutherford Memorial Lecturer, visiting Canada, perhaps, will cross the border in an official capacity, since he is sure to cross it in any case.

'Nothing was so refreshing or so inspiring,' wrote Geiger of an incident that occurred when he was at Manchester, 'as to spend an hour in this way, alone with Rutherford.' The great man has gone and no one will ever again have this felicity. The present memorial scheme has, however, the great merit that it goes as far as seems possible to perpetuate Rutherford's personality, to make his memory a living thing. A statue, a great hall, soon lose their compelling significance: of the thousands who enter the Albert Hall, how many are brought to remember the good Prince Consort? But the young man who receives a scholarship in Rutherford's name is bound to think of how the great man himself was started on his career by such a scholarship: the Memorial Lecturers will certainly be men familiar with Rutherford's work and, in all probability, will be actually engaged in developing some consequence of it. The correspondence, mostly so informal, so headlong, will be almost a living voice. We warmly commend to all our readers the memorial scheme so opportunely brought forward and so wisely planned by the Royal Society.

Pollen analysis (Palynology)

H. GODWIN

Although the Quaternary is the most recent of all geological ages, its dating presents problems which are only just beginning to be overcome. The analysis of pollen residues recovered from peat deposits and the beds of former lakes has, however, proved exceptionally helpful as a means of dating deposits, and has provided astonishingly complete information about the great climatic changes which have occurred in Europe since the last glacial age. This method of dating can be co-ordinated satisfactorily with other methods.

Pollen analysis in its modern form owes its origin to the Swedish geologist Lennart von Post, who established the analysis of quantitative changes in fossil tree-pollen as a method of attack upon the complex problems of Quaternary history. In essence, the method was one of micro-palaeontology or, perhaps better, of palaeo-ecology; it certainly had essentially geological applications, and it is in this sense that pollen analysis continues chiefly to be used and to be understood. The standard of microscopic investigation was progressively raised, particularly at the onset by Wodehouse in America. The study of pollen morphology for its own sake was developed by various workers, chief among whom is now G. Erdtman, whose institute in Stockholm has an unrivalled type-collection of pollen from various parts of the world. He has applied the results of comparative pollen morphology with much success to problems of the relationship between the families and genera of flowering plants. A useful, if restricted, field of research has been in the pollen content of honey, both recent and prehistoric, and a far wider field has been opened through research upon the allergic diseases (hay fever, etc.) associated with airborne pollen and spores. For some years, active work of this kind has been in progress in the United States upon the seasonal liberation, spread, and deposition of the pollen types most generally associated with hay fever, and in Britain valuable pioneer work has been done by Hyde and Williams from their research centre in South Wales. Pollen identifications have also been employed in research upon the biology of pollination and upon the structure and movement of glaciers. To cover all these various forms of pollen and spore investigation, Hyde has proposed the useful term palynology.

PRINCIPLES

An essential part of the reproduction of the higher plants through seeds is the prior formation and liberation of the pollen grains, and their transfer from the stamens to the receptive stigmas. The vast array of flower forms and pollination mechanisms has evolved, in response to evolutionary pressure, to perfect this transfer. The spores of mosses, ferns, and gymnosperms are dispersed by the wind, and a considerable proportion of flowering plants, like their evolutionary predecessors, still have wind-carried pollen (microspores), although insect pollination now prevails among them.

Vast numbers of pollen grains are set free into the air during flowering, even by entomophilous plants, and the small size of the liberated grains makes them fall so slowly that they can be carried long distances by air currents and reach great altitudes in the atmosphere. Only a minute proportion reaches stigmas where it can germinate successfully. The vast majority of the pollen grains gradually sink and come to rest on lakes, snowfields, oceans, and land.

Most of them are destroyed, but in some situations, especially those where oxygen is deficient, they may be embedded and preserved. This is especially so in the anaerobic muds at the bottom of lakes, and in growing peat deposits. As such deposits accumulate they bury the showers of pollen falling into them, so building millimetre by millimetre a consecutive record of the plant life of the period of formation of the deposit. The significance of pollen analysis rests upon the legibility, permanence, and informativeness of this record. The pollen grains exhibit a striking range of characters by which identification is possible, sometimes of species, very often of genera or families. There is a wide range of size and of shape; of number, shape, and disposition of germ pores or other openings in the wall; of wall structure and thickness; and of a surface morphology often involving elaborate and intricate sculptures and networks.

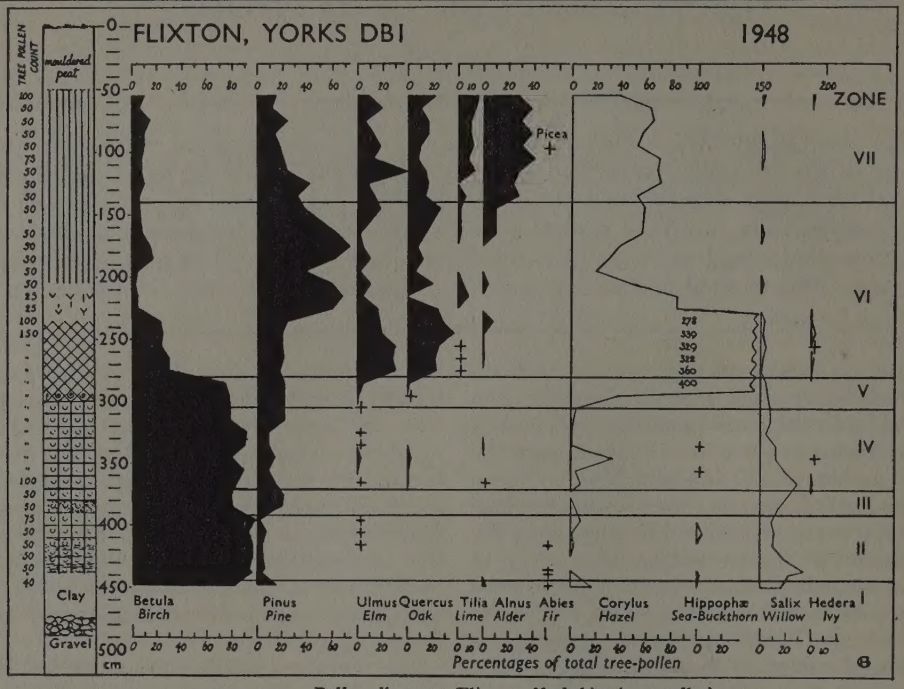


FIGURE 1 – *Pollen diagram, Flixton, Yorkshire (tree-pollen).*

The inner wall of the pollen grain is not long preserved, but the outer wall (retaining all the characters mentioned above and of quite different origin and constitution) is extremely resistant, in suitable materials remaining apparently unaltered for thousands and indeed millions of years. By simple mechanical and chemical treatments the grains may be isolated from the matrix which preserved them, and can be concentrated, mounted, and examined microscopically.

The value of the pollen identifications thus made rests not only upon the demonstration that particular species or genera have been present in the locality but even more upon the wider picture they present of the vegetational cover of a whole district or region. Since the dominant species of the great natural forest communities of western Europe are for the most part wind-pollinated trees, as are also the grasses and sedges which dominate other extensive communities, the pollen rain fully represents all of them, and it will be seen that the successive layers of a lake or peat bog can therefore picture the changing vegetational cover over long periods of time. The history of such major communities is of interest in many ways. They were, of course, the habitat, and the controlling environment, for populations of other plants and of animals, so that the history of the European fauna and flora is scarcely to be understood without knowledge of them. Equally they were the home and background of races of prehistoric human beings, whose livelihood and culture depended upon the natural environment.

Most important of all, the presence and extent of these communities were determined by prevalent climatic conditions, so that the study of past climates is implicit in the study of these past types of vegetation. It can hardly be supposed that any cause other than climatic can have been responsible for the broad sequence of change shown in the great number of pollen diagrams worked out for western Europe and North America.

A typical diagram is that shown in figure 1, which gives the results of analysing the muds from the floor of the ancient Lake Pickering which formerly existed between the Yorkshire Moors and the Wolds (England). The samples were taken by a special drill or sampler at intervals of 5 or 10 cm. For each sample the proportions of the various tree genera present are expressed (for lack of an absolute standard) as a percentage of the total tree pollen. If we consider the broad results it will be apparent that the lake deposits reflect profound vegetational changes, from a long initial

period of dominance of birch pollen, through a stage of elm, oak, and hazel (the latter in great abundance), a phase of increased importance of pine, and then, with the oak and elm joined by the lime and alder, a period in which the deciduous mixed-oak-forest trees clearly outweighed birch and pine. We may assume that the pollen represents in a rough manner the proportions of the trees from which it came, and it is apparent that this sequence of samples does in fact record the vegetational response to climatic amelioration since the last Ice Age. The time sequence of forest dominance here recorded repeats in some degree the present latitudinal sequences of forest belts governed by a similar climatic sequence. The most exigent of the tree genera, *Tilia* and *Alnus*, do not become abundant until the uppermost part of the diagram, which falls within the so-called post-glacial climatic optimum. The uppermost layers of the lake deposits have been lost by drainage and wastage, otherwise we could have seen in them the record also of climatic regression towards the cooler conditions of today; these are exhibited in the diagram from Somerset, England (figure 2).

Interesting as this single diagram is, its value is multiplied very greatly when it is compared with other diagrams compiled from suitable deposits throughout Britain or throughout western Europe. Such diagrams are found to correspond with one another to a truly extraordinary degree, and it has proved practicable to recognize over wide areas equivalent zones of vegetational development. Those for the Flixton diagram are the zones used for the British Isles; they bear a close relationship to the zoning of the nearby continent. The various regions of western Europe naturally do not show an identical history of forest evolution, but they have parallel and equivalent histories, just as today they have different natural vegetation types.

Even if we could not recognize the origin of a single fossil pollen grain, but had to refer to them by letters or by numbers, a scientific tool of great value would be in our hands, for the ubiquity of these micro-fossils, and the regularity of the changes in their frequency, clearly provide us with a time-scale against which we can record all the events of the periods covered by the deposition of pollen-bearing sediments. Knowing the identity of so many grains gives us the added power of recognizing vegetational and climatic changes.

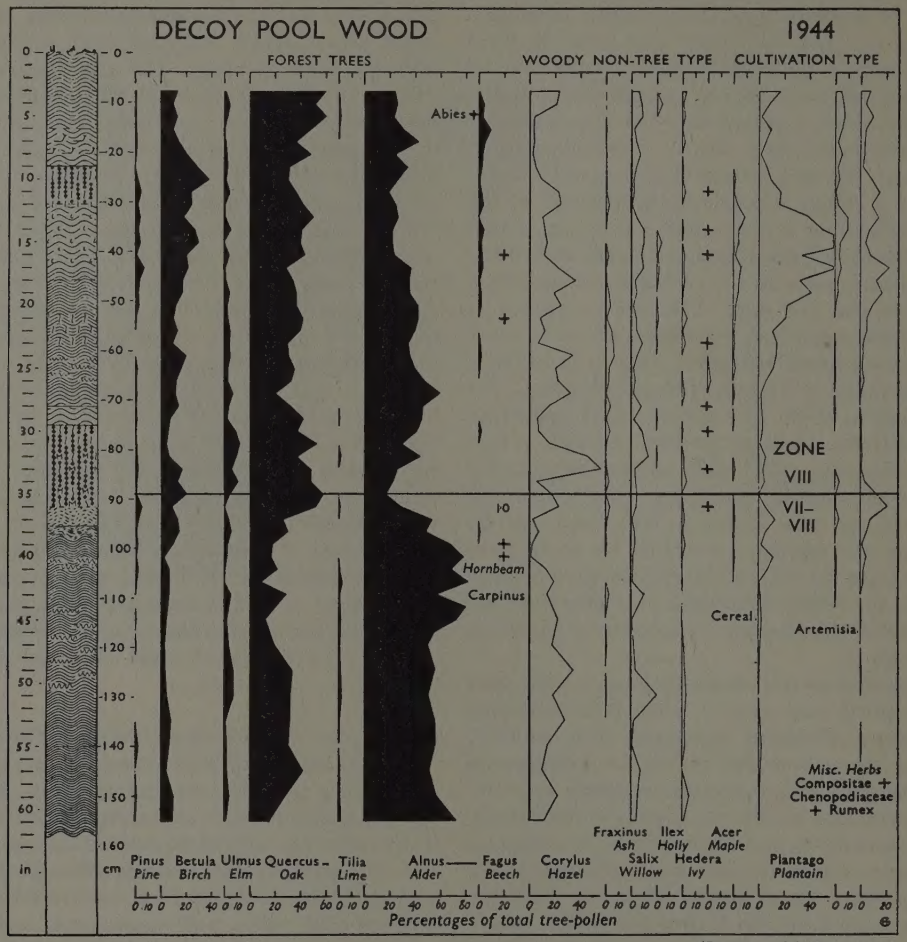
It further happens that the periods to which pollen analysis can most easily be applied, the post-glacial and the interglacial periods, are precisely those where chronological scales have hitherto been lacking. The time involved in them has been too short for the evolution and dispersal of organisms capable of serving as geological zone-fossils in the ordinary sense, and alternative indices, such as the artifacts of human cultures, occur far too locally and too sparsely. Nevertheless, geological changes have by no means ceased during this time. There have been the great and repeated climatic shifts from glacial to interglacial climates; the corresponding cycles of weathering, erosion, transport, and deposition; the alteration of ocean level by locking and unlocking of water in the world's ice-sheets; the differential bending of the earth's crust by the ice load upon it; the formation and filling of lakes; the growth of peat bogs; the modifications of rivers and coastlines; and so forth. Always associated with these have been the dependent migrations and evolution of the fauna and flora, and of man himself. It is indeed evident that, for the purpose of understanding present biological life on the earth, we must give the closest attention to all evidence of what happened in these periods.

APPLICATION TO QUATERNARY HISTORY

In making use of pollen analysis as a tool in Quaternary research, we seek to bring the conclusions which it yields about vegetational history into conformity with those derived independently from the study of archaeology, climatology, and geology. The evidence from each field has its own especial value and weaknesses, and none takes priority over the others; in the end, however attained, the results from all must form a coherent scheme.

It therefore follows that stratigraphic conditions should be sought where pollen analysis can be related to phenomena of several fields of Quaternary interest. Similarly one must constantly undertake pollen analyses of well-characterized geological situations, and settlements showing standard archaeological cultures, so that the scheme of pollen zoning can be firmly linked to as many other time-sequences as possible. Only when this has been done can pollen analysis serve the more spectacular purpose of dating objects or events of otherwise unknown age.

It is not practicable in this short space to describe even in outline the great field of Quaternary research in relation to pollen analysis, and it must suffice to refer briefly to a very few instances



(*By courtesy of the Royal Society.*)

FIGURE 2 – *Pollen diagram, Decoy Pool Wood, Somerset.*

of recent field work in Britain which illustrate the methods and objectives.

The Somerset Levels

In the valleys which extend from the Bristol Channel between the Polden Hills and Mendip there are the relics of huge sphagnum bogs, now being actively cut for peat. In this intensive excavation much evidence of value for Quaternary history has come to light, and pollen analysis has been frequently made there. The bottoms of the valleys are filled with brackish-water clay to about present sea-level, and pollen analysis of the immediately overlying peat, and of intercalated seams, shows that the marine transgression had been completed by the end of zone VI, a conclusion borne out by the pollen examination of peats submerged at depths up to 50 ft in Swansea Bay, on the Welsh side of the Bristol Channel. Although the valleys were open to the sea, it was not until Romano-British times that the sea again flooded them. Meanwhile, on the flat clay surface, reed and sedge fen grew and then gave place to so-called ombrogenous raised-bog. Such bogs, built chiefly of sphagnum, depend upon direct rainfall for their water supply, and react quickly to climatic changes. Thus, in profiles now being exposed, horizontal banding of different peat types affords evidence of past climatic change. The most striking horizon of this kind reveals on investigation that the bogs, which had become dry and covered with ling (*Calluna*)

and cotton-grass (*Eriophorum*), were suddenly covered with a deep growth of the great prickly sedge (*Cladium mariscus*) and associated fen species. This change can be interpreted only as due to flooding of the whole valley system by calcareous water from the limestone hills during a period of greatly increased wetness. The date of this event is established by two lines of evidence, pollen-analytical and archaeological. The pollen diagrams all indicate that at the horizon of this change the composition of the upland forests underwent severe changes. The lime tree greatly decreased, alder also diminished, there was a substantial increase in birch, and a smaller increase in pine, while from this time onwards beech pollen appeared in small but consistent amounts. These changes, which are used to define the boundary between pollen zones VII and VIII, were caused by a general climatic worsening found over the whole of western Europe, dated by archaeological finds to the transition from the Bronze Age to the Iron Age, and marked in innumerable peat bogs by 'recurrence surfaces' similar in character and significance to those in the Somerset bogs. The non-tree pollen confirms in detail the evidence of the gross peat analysis with regard to the plant communities growing directly on the bog throughout these changes.

As long as the climate and the bogs were dry, prehistoric man had little difficulty in crossing from ridge to ridge of solid ground, but as the swamping of the bog surfaces progressed he was forced to construct wooden trackways to maintain such routes. These could not be used for long; they were quickly engulfed in the growing morass of *Cladium*. Thus peat-diggers often encounter prehistoric trackways, and always find them at the level of the swamping surfaces. It is of great interest to discover that the timbers still carry the marks of the late Bronze Age axes by which they were cut, and that finds of middle Bronze Age spears come from only slightly lower in the bog stratigraphy. Confirmation of the age of the swamping surface comes from finds (also consistent with pollen analysis) of Neolithic pottery from substantially below, and of many Romano-British objects from substantially above, this level.

A further feature of interest is that the non-tree pollen discloses, by changes in the frequency of weed plants, the introduction, expansion, and contraction of agriculture in the region. It seems evident that cultivation occurred in the Bronze Age, suffered some setback from the climatic deterioration, and increased to much greater extent in late Iron Age and early and middle Romano-British times. The nature of the evidence for forest clearance is discussed later. The pollen curves of figure 2 show most of the major features to which we have referred.

Lake Pickering, Yorkshire

The retreat of the last ice sheet from east Yorkshire left a long, shallow lake ponded up at the seaward end. Through the waters of the lake morainic islands rose at intervals, and recent discoveries have shown that many of them were densely occupied by prehistoric hunters. Series of borings across the deepest parts of the lake show a stratigraphy typical of the late glacial period, and a long pollen series yields the diagram already described. Excavation on the flanks of one of the islands has shown that the prehistoric occupants built extensive platforms of birch branches beside the shore, in and upon which there is a great wealth of archaeological material: flint, antler, bone, wood, bark, and even amber, preserved by submergence in the rising water of the lake. It is evident from the artifacts that the site was occupied by Mesolithic people who had affinities on the one hand with the upper Palaeolithic cultures of Meiendorf in Holstein, and on the other with the Maglemose cultures of Denmark, the one late Glacial in date and the other Boreal, that is to say from the period of first expansion of the mixed-oak-forest.

At Flixton, the earliest of the Lake Pickering sites to be investigated (though not the most productive), it was possible to trace the débris of the occupation site laterally into the lake deposits, and so to bring it within a short vertical pollen series. This latter, fitted to the long lake-series, shows clearly that the occupation must be referred to the stage of closed forest immediately before the expansion of hazel and the mixed-oak-forest. It is thus earlier than any previously described Mesolithic culture in Britain. Nevertheless it seems apparent that, falling as it does near the close of zone IV or the opening of zone V, it relates to a period of closed forests, though these were birch and pine only.

This conclusion is confirmed by the identification of the abundant remains of forest animals. These include great quantities of the red deer (*Cervus elaphus*), some elk (*Alces alces*), roe deer (*Capreolus capreolus*), pig, a large species of *Bos*, and the fur-bearing fox, martin, badger, and beaver. There have been found various stages in the

manufacture of barbed spears from the red-deer antlers; the abundance of these completed implements strongly characterizes the cultures, and it is interesting to note that in two previous instances of their discovery in Britain it has been possible to date them by pollen analysis. One of these was at the nearby cliff-site at Skipsea, where the implements were shown to have been at least as old as the Boreal period. The other was the recovery of such an implement from a lump of peat dredged from the floor of the North Sea in 19 fathoms of water by a trawler fishing on the Leman and Ower banks. Samples of peat attached to the mineral ground at this site were analysed, and were shown to have formed in the period just before and during the first expansion of the hazel and the mixed-oak-forests. It is therefore evident that at the time of this Mesolithic settlement in Yorkshire the North Sea basin was still dry, and that not only might the folk of the time have crossed directly between Britain and the continent of Europe, but that some of them did.

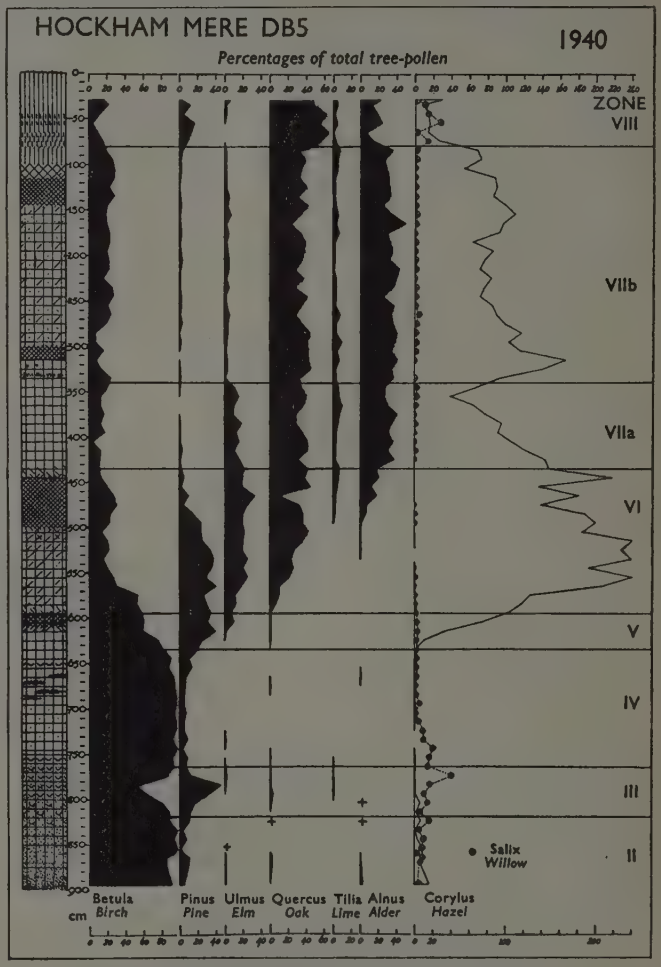
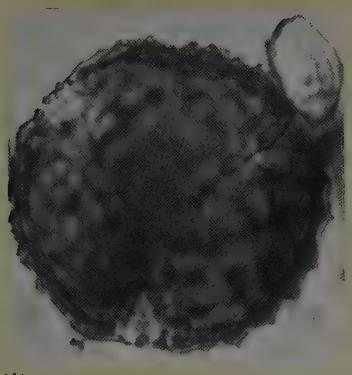


FIGURE 3 – *Pollen diagram, Hockham Mere (tree-pollen).*

DEFORESTATION AND HUMAN INFLUENCE

The technique of pollen analysis was based, as we have seen, very largely on the premise that the vegetational changes which it records are universally co-ordinated, since they have a common climatic cause. In the natural ecosystems of the remote past, man, hardly less than other animals, was subject to environmental control, and the hunter and fisher had an economy, tools, and customs immediately related to the forest or tundra in which he lived. Gradually this relation altered; the stone axe, fire, domesticated animals, metal tools, and tillage were agencies by which man began himself to exert influence upon his natural surroundings. At first puny, these efforts have gained the power and momentum which today call for the fullest efforts of conscious conservation policies if the very means of survival of humanity are not to be destroyed by them. The initiation and progress of this process are also, like the preceding 'natural' evolution, to be found recorded in the pollen diagrams of western Europe.

It has been known for some time that in a general way it is possible to distinguish the pollen of cultivated cereals from that of most wild grasses —a matter chiefly of size—and it has been shown that pollen of 'Cerealia' type was represented in some German diagrams by continuous curves from the Middle Ages onwards. Only within the last decade, however, has it been demonstrated that Neolithic forest clearance could be unmistakably recognized. Iversen, working in Denmark, was able to show that, at certain lake sites, ash from recognized Neolithic shore settlements was embedded in the lake muds at levels where the tree-pollen curves indicated sudden but orderly displacements. The curves showed, in fact, the local clearance by fire of the dominant oaks, the



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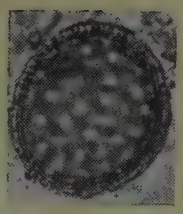

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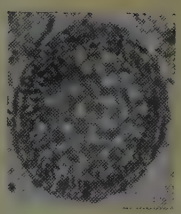

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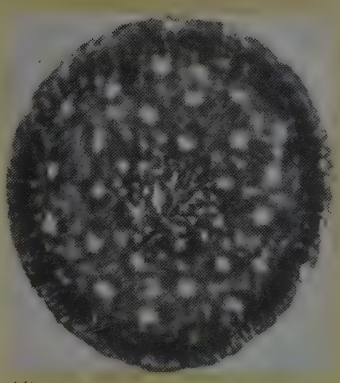

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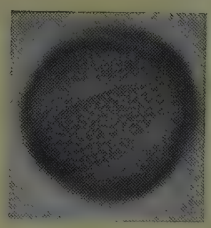

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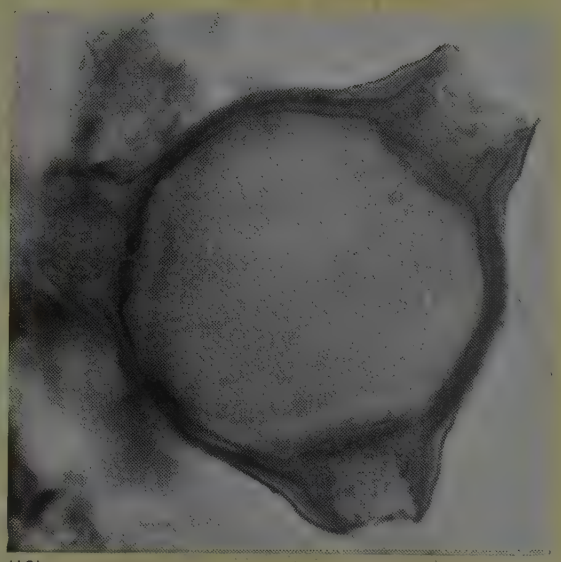

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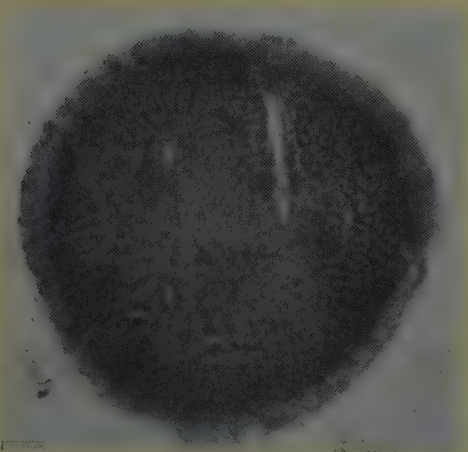

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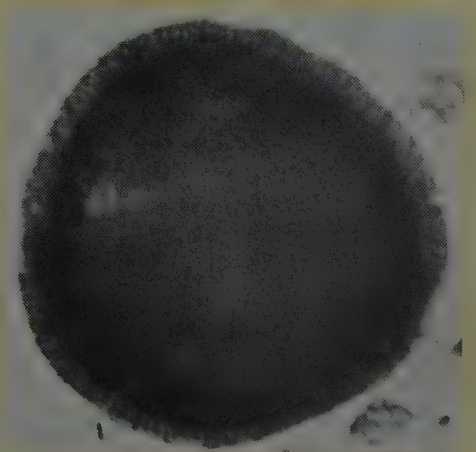
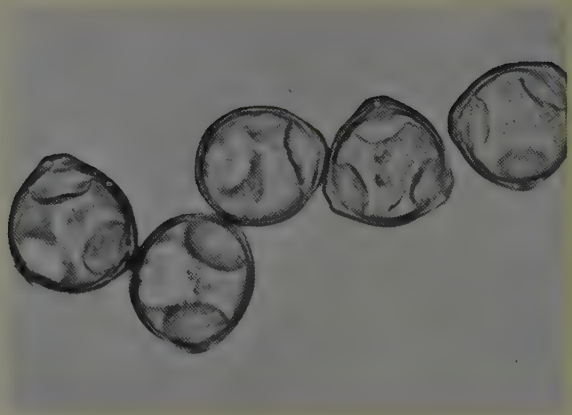
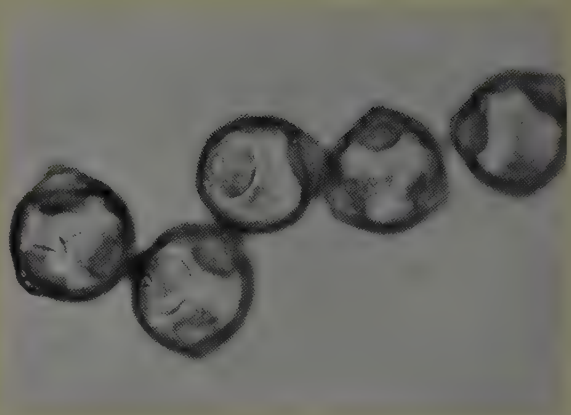


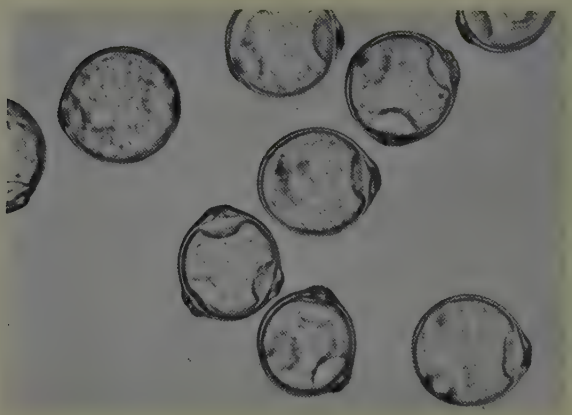
(12) (× 1000)

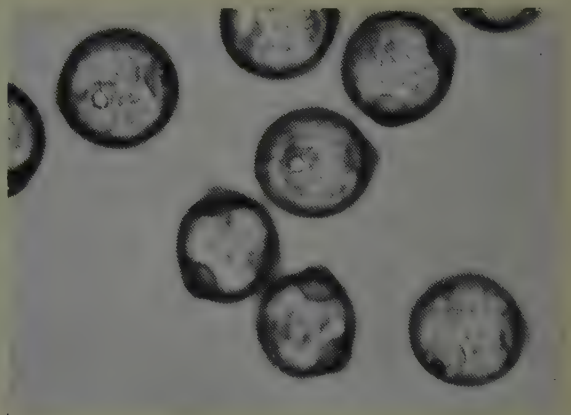
FIGURE 4 – *Photographs of fossil pollen grains from late-glacial muds at Nazeing in the Lea Valley, north of London.* (1) Valeriana*;* (2) *and* (3) Polemonium caeruleum *in two planes of focus to show the characteristic pores and wall structure;* (4) *Recent pollen of the same species for comparison and at higher magnification;* (5) Helianthemum *cf.* chamaecistus*;* (6) Artemisia *sp.;* (7) Ulmaria*;* (8) Chenopodium *sp.;* (9) *six-furrowed grain of the* Labiatae*;* (10) Epilobium *sp.;* (11) *and* (12) Succisa pratensis, *the same grain at two depths of focus.*





FIGURES 5 *and* 6 – *Pollen grains of* Corylus avellana (*hazel*) *in optical section and in surface view, showing the characteristic pores.* (× 800)





FIGURES 7 *and* 8 – *Pollen grains of* Betula pendula (*birch*) *in optical section and in surface view. Note how the pores differ from those of* Corylus. (× 800)

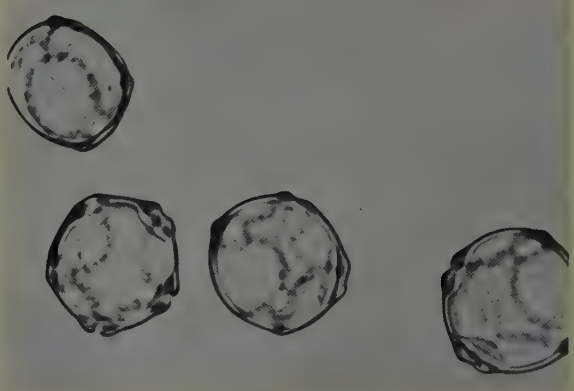


FIGURE 9 – *Pollen grains of* Alnus glutinosa (*alder*), *showing the curved bands running internally between the ringed pores.* (× 800)

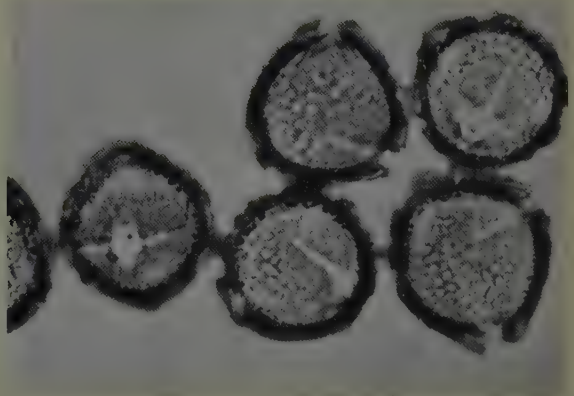


FIGURE 10 – *Pollen grains of* Hedera helix (*ivy*), *showing three furrows, each with a central circular pore, and a heavily sculptured surface.* (× 800)

(Photographs 5–10 published by courtesy of Mr H. A. Hyde and of the Asthma and Allergy Research Unit, St David's Hospital, Cardiff.)

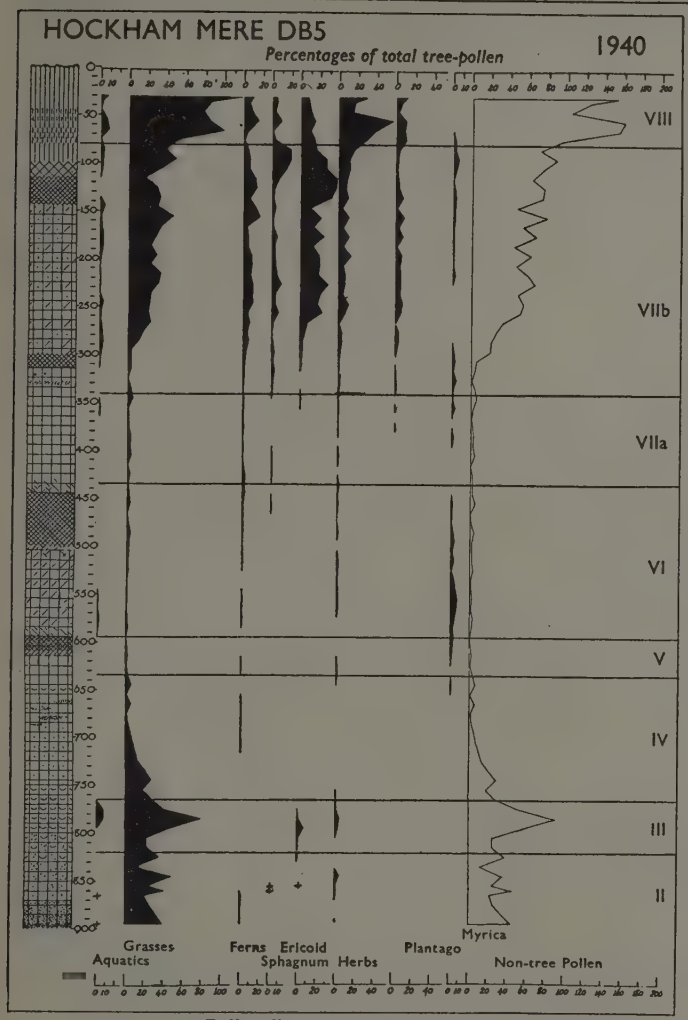


FIGURE 11 – *Pollen diagram, Hockham Mere (non-tree pollen).*

temporary increase of hazel, birch, and alder which colonized the gaps after their abandonment, and finally the re-establishment of mixed forest. More important than this, they showed the presence of cereal pollen, and the pollen of several species or genera of plants still regarded as weeds of cultivated ground, or at least as characteristic of broken or open sites. Prominent among them is the ribwort plantain (*Plantago lanceolata*), pollen of which can be distinguished from that of other plantains, and *Artemisia*, a genus of wind-pollinated *Compositae*. For the sandy heath country of Jutland, Iversen was able to confirm that the treeless heaths of the present day originated in prehistoric oak-birch forest; the easily recognizable pollen of the dominant heath shrubs (*Calluna* and other ericoid genera) extended back only to the Iron Age, before which the landscape was occupied by almost continuous forest.

These discoveries had their counterpart in Britain, where similar investigations had been made in the great heathland areas of East Anglia, the so-called Breckland. An ancient lake in the north of this region, Hockham Mere, partially drained in Tudor times, was shown still to contain 10 or 12 metres depth of organic lake mud, which when pollen-analysed revealed the history of the surrounding land right back to late glacial times. The tree-pollen diagram (figure 3) is remarkably uniform, and is clearly undisturbed by local influences such as complicate the diagrams of lake margins, wooded fens, and bogs. In it may be recognized all the leading features of the British pollen zonation. We may note that at about 330 cm falls the boundary between zones VII*a* and VII*b*, where the sharp decline in importance of the elm is a feature of all west European diagrams; this is known to correspond with the beginnings of Neolithic culture. To this diagram we add that for the non-tree pollen to which the same zones have been transferred. It will be observed that during the late glacial period (zones II and III) the openness of the birch woodland is demonstrated by the high values for non-tree pollen, chiefly grasses. Following this, however, is a long period in which the total non-tree pollen never amounts to 10 per cent. of the tree pollen; this must indicate closed forest conditions. At about 300 cm the diagram shows a startling change, and pollen of grasses, heather, and miscellaneous herbs increases remarkably, together with the spores of sphagnum and of ferns. They quickly equal 60 per cent. of the total tree pollen, and evidently indicate the conversion of much of the forest into open heaths. It will be observed that during this time there is established a continuous curve for that characteristic species, *Plantago lanceolata*.

Deforestation thus evidently became serious in Neolithic times, and it is significant that within 10 miles (16 km) of Hockham Mere is the great

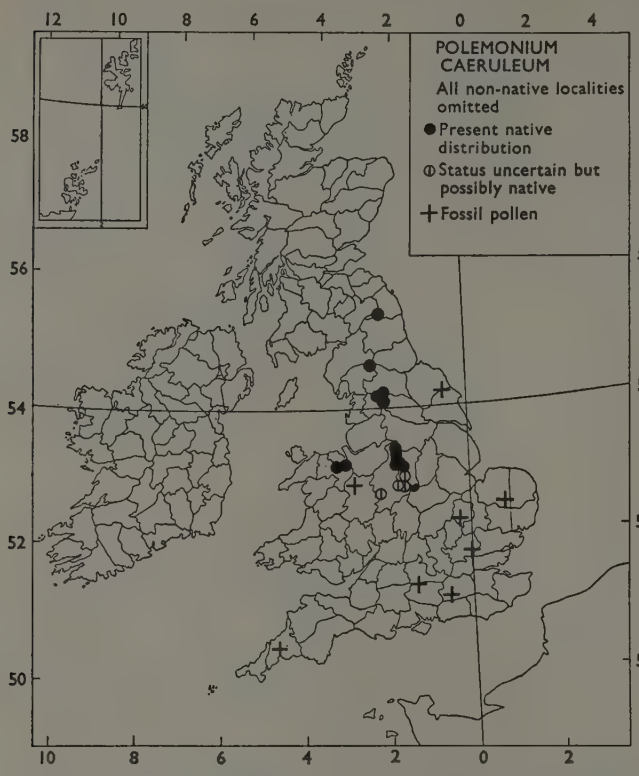


FIGURE 12 – *Present and former distribution of* Polemonium caeruleum *in the British Isles. The discoveries of pollen in late glacial deposits show how extensive has been the range of the plant, which has been found at points as widely separated as Cornwall and the Scottish border.*

Neolithic flint mine of Grimes' Graves, furnishing direct evidence of prehistoric occupation at this period. At a depth of 70–80 cm the non-tree pollen curves show substantial increases, and these may be dated by reference to the tree-pollen diagram, where a series of modifications indicates the transition from zone VII to zone VIII in response to the widespread climatic deterioration of that time. This falls at the transition from Bronze Age to Iron Age in Britain, and it seems evident that the clearances which began in Neolithic times were greatly extended in the Iron Age. The explanation of the Breckland heaths in terms of such anthropogenous origin represents a considerable step forward in understanding the ecology of this region.

THE LATE GLACIAL PERIOD

As the picture of the post-glacial forest history of western Europe began to take unmistakable shape, pollen analysts began to thrust back their inquiries into the preceding late glacial period. They examined the phenomena associated with the so-called Allerød oscillation, a temporary phase of warmth followed by returning cold, which occurred immediately before the general post-glacial climatic amelioration. This oscillation is represented by organic lake and basin deposits overlying glacial till (boulder clay) and covered by earth brought down into the basin by alternate freezing and thawing. The climatic improvement of the oscillation was indicated not merely by the fact that organic muds unmixed with mineral matter grew in the lakes, but by the relatively temperate flora of these organic muds, as indicated by fruits, seeds, leaves, etc., in contrast with the more northern flora of the mineral soils above and below, which gave to these layers the names of the lower and upper Dryas clays.

The application of pollen analysis to deposits of this period was much facilitated by improvements in experience and technique, which by then allowed pollen of many herbaceous genera to be recognized. In southern Scandinavia, where these investigations began, it was soon realized that the lower Dryas clays, the Allerød layer, and the upper Dryas clays had clear expression in the pollen diagrams, and they have been equated there and in Britain with pollen zones I, II, and III. The post-glacial period which begins with zone IV opens by a remarkable reduction in the ratio of non-tree pollen to tree pollen, a constant expression of the development of closed birch woods, and the exclusion of herbaceous vegetation. The late glacial non-tree pollen was overwhelmingly derived from grasses and sedges, the ericoid shrubs of modern Europe north of the forest line being unimportant. The frequency of pollen of birches, and local macroscopic fossils, show, however, that clumps of these trees occurred here and there, and the name park-tundra has been coined to express the general character of the vegetation. Certain species and genera have come to be recognized through their pollen as very highly characteristic of this late glacial vegetation. *Salix* (willow) is recognizable and abundant, but although

most species are not separately identifiable, one may presume that the pollen comes from the northern dwarf species, just as the smallest birch pollen probably derives from *Betula nana*. *Hippophae rhamnoides*, the sea buckthorn, is often present in zones I and III in western Europe but seldom occurs in Britain. *Artemisia* is constantly present, and also pollen of *Helianthemum* (the rock rose), but in neither instance is the species certainly known. Pollen of *Thalictrum* (possibly *T. alpinum*), *Rumex*, *Armeria*, *Dryas*, *Galium*, *Ulmaria*, *Campanula*, and a great many more also occurs freely. In the north-west of Ireland, *Empetrum* pollen occurs in such large amounts as to suggest the presence of *Empetrum* heaths, and the species can be recognized as the true *E. nigrum* L., not the more northerly *E. hermaphroditum*. Pollen of *Juniperus* and *Populus* has been identified by some of the more experienced analysts, and the spores of *Selaginella* and *Botrychium* are abundant.

In the Allerød period itself, the park-tundra vegetation was to a varying degree suppressed by the development of closed woodlands, and Iversen's pollen maps of southern Scandinavia for this period indicate that while in northern Denmark and Sweden the woods were of birches, in northern Germany pine forest temporarily prevailed. The new knowledge of the late glacial park-tundra vegetation accords remarkably well with the increasing recognition of the abundant fauna of herbivorous mammals—bison (*Bison bonasus arbusto-tundrarum*), horse, reindeer, and elk (*Alces alces*). It is of the greatest interest that practically all the finds of skeletons or antlers of the giant Irish deer (*Cervus megaceros*) from Ireland have now been shown by Mitchell and Jessen to have come from the chalk marls of the Allerød period. It seems impossible not to link the extinction of this great beast with that extension of the forest which at once reduced its grazing and gave shelter to predators.

This deduction affords an opportunity of commenting on the facility with which animal remains may be referred by pollen analysis to the period of their origin, not merely when found undisturbed *in situ* in deposits, but also whenever an isolated horn core or bone can yield a few cubic millimetres of dried mud for a pollen analysis.

Naturally, the principle applies no less to plant remains. In several instances we have collections of seeds, fruits, and leaves which permit the recognition of numerous species, and their allocation to the late glacial is confirmed essentially by pollen analysis of the deposits from which they come. A large collection of this kind has recently been made at Nazeing, in the Lea valley, a little north of London. Among many features of interest presented by it we may note two: firstly, the presence of many species of plants now behaving in Britain as weeds of cultivation or waste-land plants, and until now regarded as introduced by prehistoric agriculturalists. These include *Galeopsis tetrahit*, *Sonchus asper*, and *Linaria vulgaris*, discoveries which recall the identification of late glacial pollen of the corn-flower (*Centaurea cyanus*) in Denmark and East Anglia, and of the wild parsnip (*Pastinaca sativa*) in Britain.

Secondly, we may note the presence of many species widely outside their present British range, and among them some whose distribution is today strikingly scattered. In this class are fruits of *Potentilla fruticosa*, *Thalictrum alpinum*, *Dryas octopetala*, and *Betula nana*, among others. Even more striking is the presence of considerable amounts of the pollen of Jacob's ladder, *Polemonium caeruleum*, a handsome plant with elaborate pollen easily distinguished from that of other species (see figure 4), and with a present restricted and scattered distribution. There has been a strong tendency to interpret the local and restricted ranges of species such as these in terms of survival *in situ* through at least the last glaciation, but as will be seen from the map (figure 12), *Polemonium* has been found as a fossil so often in Britain that it cannot be doubted that it had a very wide distribution in late glacial times.

Indeed, at this time of open immature and mobile soils, still not stratified by leaching from upper layers and deposition in lower ones, when forest competition was absent, and the North Sea basin was still land, conditions for dispersal must have been remarkably favourable for a very large range of plants, especially those we now regard as weeds and plants of open habitats. In the ensuing post-glacial period, however, the spread of forests and peat mires, and the leaching of soils, all greatly restricted the range of such species. In short, post-glacial events must have been responsible for some, and perhaps many, of the so-called relict distribution ranges hitherto explained as due to per-glacial survival.

INTER-GLACIAL AND OLDER DEPOSITS

One of the outstanding and urgent tasks of pollen analysis is to throw light upon the nature of the British inter-glacial deposits, to co-ordinate them with similar deposits on the European continent and so possibly to assist in the vexed problem

of correlating British and extra-British glacial phenomena. There is already some ground for supposing this to be feasible. More than twenty years back, Jessen and Milthers published the results of their intensive investigation of pollen and other fossil material from Denmark and northern Germany, and subsequent investigations have strengthened their main conclusions. They were able to demonstrate, by pollen diagrams for deep lake-deposits, that the climatic vegetational history of each inter-glacial period followed a course essentially similar to that of the post-glacial, but continuing of course into a succeeding glaciation. Nevertheless, certain features appear to have characterized the various inter-glacials; thus, during the last of them, hornbeam (*Carpinus*) came to play such a dominant role in the deciduous woodlands as apparently it had neither done before nor has done since in north-western Europe. When, during recent months, hornbeam pollen was recovered in substantial amounts from organic muds of an inter-glacial gravel terrace in Cambridge, England, this fact pointed a possible reference to the last inter-glacial period. Among the identifications of warmth-demanding species were the fruits of *Naias minor*, a water-plant of central and south-eastern Europe, not known as a living plant in Britain, although known from other inter-glacial deposits here. Wolstedt has recently exhibited a short pollen diagram completed by P. W. Thomson for part of the famous Cromer Forest bed. Jessen and Mitchell have briefly reported on pollen analyses in progress upon Irish inter-glacials, and it is evident that we may expect much information to illuminate this field of inquiry.

There is no need, however, to suppose that pollen analyses must be restricted to the Quaternary period, although before this period the identity of the pollen types encountered becomes less certain, and the aims are correspondingly in somewhat different directions. On the one hand we have the remarkable (and still largely unpublished) work of Simpson on the Tertiary plant beds of western Scotland, in which there has been found a wealth of pollen types referable to genera such as Eucalyptus, and even of the living fossil *Metasequoia* so recently discovered growing in China. These are genera now characteristic of far-distant regions of the globe, and their presence indicates great plant migrations. On the other hand, we have in progress in many parts of the world intensive research upon the pollen and spore content of brown coals of Tertiary age, research aimed in part at discovering methods of correlation and dating. Although many of the types are not referable to living plants, important conclusions nevertheless emerge from their study. We may note that Thomson has been able to show of the lignites of north-western Germany that the parent materials were formed in communities corresponding to the wooded fens and to the great heath-clad sphagnum bogs of post-glacial times, each type exhibiting its own characteristic pollen picture derived from the local vegetation growing upon it during formation.

From Jurassic deposits there has been recovered a pollen grain of undoubted dicotyledonous type —perhaps our earliest evidence of this great group of plants—and, although it may be stretching the term pollen analysis to include it, we must note that spore analysis is a practicable and useful method now employed for characterizing particular seams of coal in our prolific Carboniferous coal measures.

Pollen analysis as a means of Quaternary research has been far more intensively developed in western Europe than elsewhere, but a substantial volume of research has been completed in North America, and enough has been done in New Zealand, Patagonia, and other distant regions to give colour to von Post's vision that planned and co-ordinated research of this kind may ultimately give a global picture of Quaternary climatic changes. There seems a very fair prospect that the radio-carbon dating developed by Libby may supply us with a more direct method of dating fossil organic materials than is afforded by pollen analysis. Should this be so, it would become possible at once to co-ordinate pollen diagrams from distant parts of the world, and correspondingly to accelerate research into many aspects of Quaternary history.

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Flames: their structure and radiation

A. G. GAYDON

Although the study of flames presents many technical difficulties it is rewarded by results of considerable practical and theoretical importance. The mechanism by which carbon is formed in flames is important both to the metallurgist and to the designer of internal combustion engines. The study of the radiation emitted has led to advances in knowledge of the chemical processes involved, and of the way in which energy is transferred between molecules.

Flames may be classified into two general types, those of premixed gases, and those of a combustible gas burning by diffusion in a supporting atmosphere. The most familiar form of the premixed flame is that given by a Bunsen burner. A candle flame is an example of the diffusion flame. With the air-holes of a Bunsen open to give full aeration we see a relatively bright blue-green inner cone and a surrounding sheath or outer cone of a pale blue-violet colour. This is illustrated in figure 4, which shows a flame of ethylene premixed with air.[1] The inner cone is the flame front in which the chemical reactions of the combustion occur. The flame may be regarded as a continuous explosion travelling against the gas stream, and the velocity may be determined approximately by measuring the angle of the cone and the rate at which the unburnt gas mixture is flowing. The flame front is very nearly conical in form but is slightly splayed out near the burner rim, where the flame velocity is reduced by the presence of the cool burner wall; it is slightly rounded at the top, where the velocity is somewhat greater because heat and active radicals are being supplied three-dimensionally from all sides at this point.

If the air supply is reduced a little (figure 5) the flame velocity falls and the inner cone consequently becomes longer. It is also less bright and has a luminous yellow tip, the yellowness being due to radiation from small incandescent particles of carbon. If the air supply is completely stopped (figure 6) the flame becomes yellow, owing to carbon formation, throughout its length, apart from a weak blue-violet region surrounding the base of the flame. This is the typical appearance of a diffusion flame of a hydrocarbon burning in air.

[1] Colour photography has rather serious limitations when dealing with self-luminous sources. Considerable trouble has been taken to make the colours in the plates as nearly true as possible, but perfect reproduction has not been achieved.

While most premixed flames with which we are familiar show a marked inner cone, this is not an essential property of all flames. The flame of hydrogen with air or oxygen does not show any visible inner cone, nor is there any increase of ultra-violet radiation from the flame front. The appearance of a bright inner cone is most characteristic of organic compounds, although it is also found in other flames, such as oxy-ammonia. In some very hot flames, such as oxy-acetylene, there is a bright mantle surrounding the inner cone when the fuel is in slight excess.

It is possible to separate the inner and outer cones of a flame with a Smithells' separator. In this device the burner is enclosed in a fairly closely fitting tube of glass or quartz which projects an inch or so above the burner tip. By adjustment of gas-flows it is possible to get the inner cone to settle on the inner burner rim, while the outer cone forms on the top of the glass tube, as in figure 7. It should be noted that there is practically no radiation from the region between the two cones, i.e. from the hot interconal gases. Chemical sampling shows that these interconal gases consist mainly of hydrogen, carbon monoxide, water vapour, and nitrogen, the organic compounds being almost completely broken down in the inner cone. The outer cone may thus be identified with the diffusion flame of the hydrogen and carbon monoxide.

An interesting, and still incompletely solved, problem is the mechanism by which carbon is formed in flames. It is of considerable industrial importance, for example in the design of open hearth furnaces and internal combustion engines. In premixed flames, the formation of carbon is quite sensitive to the presence of catalysts; thus Whittingham and the author [1] have shown that one part in a thousand of sulphur trioxide added to the gases in a fully aerated Bunsen flame will cause the flame to turn yellow; sulphur dioxide, on the other hand, reduces the tendency to carbon

formation. In diffusion flames, however, catalytic effects are unimportant.

In diffusion flames the mixing processes are relatively slow, and it is unlikely that there is any marked departure from equilibrium conditions. For premixed flames, however, the gases pass through the very thin reaction zone in a time of the order of a hundred-thousandth of a second, or for flames with oxygen in less than a millionth of a second. In these very short times it is probable that the fuel molecules are polymerized by some rapid chain-reaction processes, probably initiated by active free radicals, before breaking down to form solid carbon.

It is obvious that in the flame front the chemical reactions are proceeding so rapidly that it is not possible to take samples or follow the processes by ordinary chemical methods. Some information can be obtained by studying the effects of additives on flame velocity and combustion limits, or by analysing the radiation from the flame itself. We find that in organic flames many chemically unstable free radicals, such as OH, CH, C_2, and HCO, are present in the flame front or inner cone. A review of this aspect has recently been given by Barrow [2], and a more complete treatment of the subject by the author [3]. Existing chemical theories of combustion processes do not make use of, or account for, the presence of many of these radicals (CH, C_2, HCO), yet their radiation is the most characteristic feature of the combustion, and in suitable cases may easily be used empirically to identify the type of combustion occurring.

The mechanism of formation of C_2 and CH radicals in flames is unknown, but it seems at least fairly certain that it is not a very simple one. The bands of C_2 and CH are emitted much more strongly by flames very rich in fuel. It has recently been found by the author and Wolfhard that if, in a flame of a hydrocarbon, the hydrocarbon is partially replaced by some other combustible, e.g. hydrogen or carbon monoxide, in such amount as to keep the mixture at the same strength, then the amount of the C_2 and CH radiation falls off surprisingly rapidly. These results seem to show that the formation of C_2 and CH is not due to direct simple reaction between fuel and oxygen.

Pannetier and the author [4] have found that a flame of dry cyanogen burning with dry oxygen emits the C_2 and CN bands very strongly, but that the addition of a little moisture or hydrogen causes a remarkable decrease in the C_2 radiation; emission from CH radicals then occurs, suggesting that C_2 may react with OH or H_2 to form CH.

A striking result is obtained by adding a little nitric oxide to a flame. In many cases this produces a yellowish-green coloration due to the reaction:

$$NO + O = NO_2 + \text{radiation}.$$

This serves as a qualitative test for the presence of atomic oxygen in the flame. Figure 7 shows an ethylene-air flame burning in a Smithells' separator. Figure 8 shows the same flame with a little nitric oxide added. The inner cone is more violet, owing to emission of radiation from CN radicals, and the outer cone has changed to a greenish shade, owing to the presence of atomic oxygen in that region. The greenish shade is absent from the interconal gases, and it can be shown that its characteristic continuous spectrum is not emitted from the inner cone. This shows the absence of appreciable quantities of atomic oxygen during the initial combustion of the hydrocarbon.

In flames at atmospheric pressure, the flame front in which the main chemical reactions occur (corresponding roughly to the luminous inner cone) is only of the order of a fiftieth of a millimetre thick, and since the flame is usually roughly conical in form it is not possible to study the radiation from the flame front in any detail. In recent work the author and Wolfhard [5] have been able to learn something of the detailed structure of the flame front by running flames at very low pressure. The flame is enclosed in a large Pyrex vessel which is continuously evacuated, a burner of large diameter being used. The flame is viewed through a quartz window. It has been found possible to maintain steady flames at pressures below a hundredth of an atmosphere (for oxy-acetylene a pressure of 0·9 mm mercury has been reached). In these flames the flame front is much thicker—it may be of the order of a centimetre or so—and the flame can be made flat, so that the radiations from the base and top of the reaction zone can be studied separately. For hydrocarbons burning with oxygen, such as the oxy-acetylene flame shown in figure 2, the blue-green flame has a greenish base and a more violet top. By projecting an image of the flame on to the slit of a spectrograph we find that the spectrum (figure 1) shows the yellow-green, green, and blue-green bands of C_2 most strongly at the base of the flame, while the blue-violet and violet bands of CH are emitted rather higher in the flame, causing the violet colour at the top. One might have expected that in the oxidation of a hydrocarbon CH would be formed before C_2, but the reverse appears to happen.

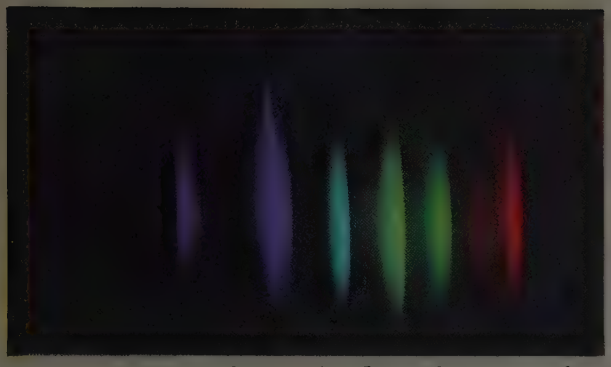


FIGURE 1 – *Spectrum of oxy-acetylene flame at low pressure, showing violet and blue-violet bands of CH higher than blue-green, green, and yellow-green bands of* C_2.

FIGURE 2 – *Oxy-acetylene flame at a pressure of about 3 mm of mercury, showing structure of flame front.*

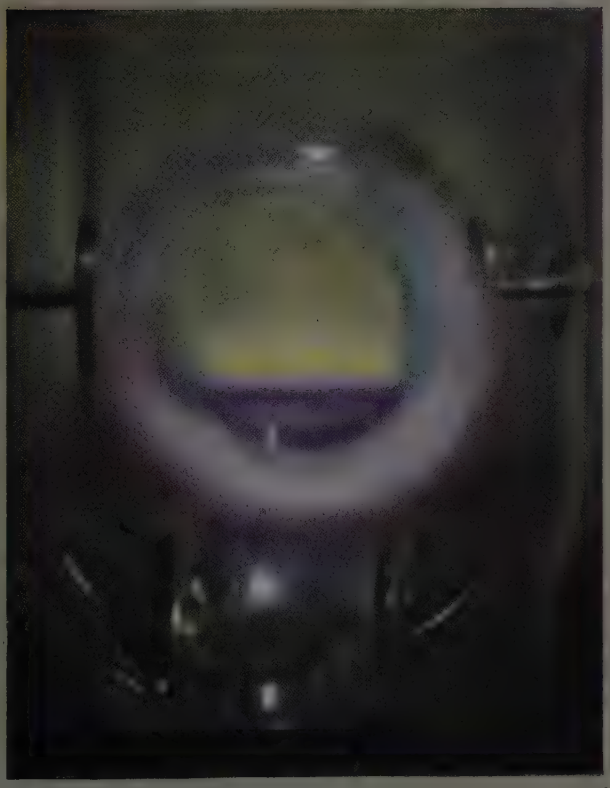


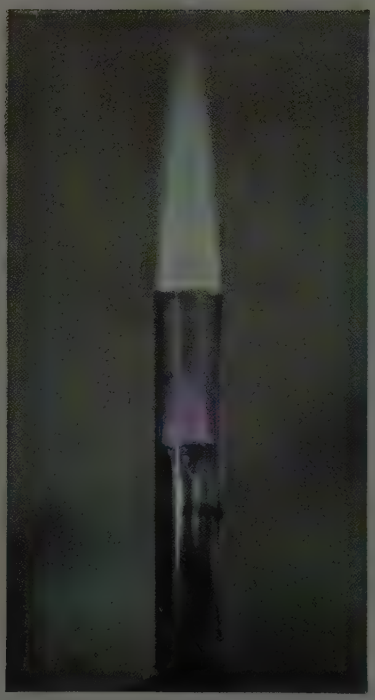
FIGURE 3 – *Acetylene and nitrous oxide flame at about 10 mm of mercury.*

(4)

(5)

(6)

(7)



(8)

FIGURE 4 – *Premixed flame of ethylene and air; full aeration.*

FIGURE 5 – *Premixed ethylene-air flame; aeration reduced.*

FIGURE 6 – *Ethylene-air. Diffusion flame.*

FIGURE 7 – *Ethylene-air flame on Smithells' separator.*

FIGURE 8 – *The effect of adding nitric oxide to an ethylene-air flame.*

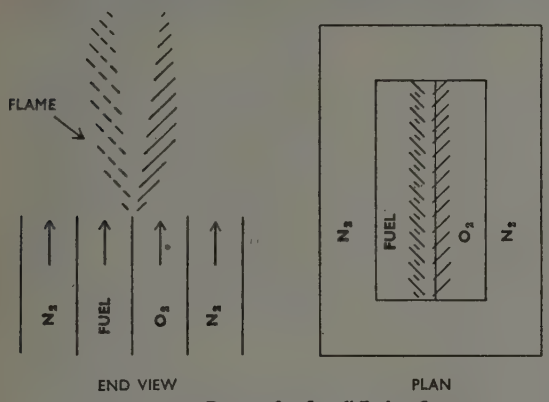


FIGURE 9 – *Burner for flat diffusion flames.*

Figure 3 shows an interesting flame of acetylene mixed with nitrous oxide. This has a rather thin, intensely bright, violet reaction zone, the emission from which is due mostly to CN radicals, with a greenish-yellow glow above, which is probably due to reaction between nitric oxide and atomic oxygen.

The structure of diffusion flames can also be examined in detail, and Wolfhard and Parker [6] have designed a burner for this purpose (figure 9). The central part is rectangular in form and is divided into two, with fuel passing up one section and oxygen up the other, so that combustion takes place along the straight division. This rectangular burner is enclosed in a second rectangular jacket up which there is a flow of nitrogen to isolate the flame from the surrounding air. The flame can then be studied edge on. For hydrocarbons, such as ethylene or methane, there is a bright yellow region of flame on the fuel side, due to carbon formation. This is separated by a dark region from a bluish zone on the oxygen side. This bluish zone shows emission from C_2, CH, and OH radicals, and on the oxygen side of the zone there is also some emission of the Schumann-Runge bands of oxygen itself. It may be noted that here the C_2 appears to be formed after, not before, the solid carbon. With this type of flame it is possible both to study the emission spectrum and to record the absorption. Hot oxygen itself shows absorption in the far ultra-violet, just within the range of quartz instruments, and by choosing a suitable fuel, such as benzene, the absorption of the fuel also can be followed. It is found, rather surprisingly at first sight, that there is no appreciable contact between oxygen and fuel, the fuel being decomposed thermally to hydrogen, carbon, and other products before it reaches the oxygen. The region just on the fuel side of the yellow carbon-formation zone shows continuous absorption in the ultra-violet; this may be due to the polymerization of fuel which occurs before carbon formation.

Radiation gives information about physical as well as chemical processes. The diffusion of OH radicals back against the gas stream can be followed by means of absorption spectra, and results suggest the important role of diffusion in flame propagation. By detailed examination of band spectra we can determine the average amounts of rotational and vibrational energy possessed by the emitting molecules, and by studying the Doppler broadening of the spectrum lines we may in favourable cases even get at the average translational energies of the molecules. This is yielding some information about the processes by which energy is transferred to and from molecules. In many cases the amount of rotational energy present in the emitting molecules corresponds to very high temperatures (5000–10,000° C) and can be due only to the excitation resulting from the chemical processes.

Besides the natural emission from the flame, it is found [7] that when suitable metals are added to the flame gases, then the spectra of these metals are much more strongly and fully excited in the flame front than in the region just above or in the outer cone. This occurs for many organic flames and a few inorganic flames, such as oxy-ammonia, but not for hydrogen, carbon monoxide, or even some flames which do show inner cones, such as those of formaldehyde and carbon disulphide. This effect, which has only recently been discovered, has not yet been explained. There is also evidence that the ionization in flames, especially in the inner cone, is higher than would be expected on thermal grounds.

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Hormones and the metamorphosis of insects

V. B. WIGGLESWORTH

'Those strange and mystical transmigrations that I have observed in Silk-worms,' wrote Sir Thomas Browne, 'turned my Philosophy into Divinity. There is in these works of nature, which seem to puzzle reason, something Divine, and hath more in it than the eye of a common spectator doth discover.' Who, indeed, he says, can fail to wonder 'at the operation of two Souls in those little Bodies'?

The contemplation of the metamorphosis of insects has always evoked feelings of mystery. When regarded more closely through the eyes of the anatomist and the experimental biologist, the superficial mystery is dispelled—to be replaced by deeper mysteries.

Even in that extreme example, metamorphosis in the Lepidoptera, where the caterpillar is transformed into the chrysalis and the butterfly, the rudiments of the organs of the adult or imago—the wings and legs and so forth—are already present in the young larva as clusters of undifferentiated cells, the so-called imaginal disks. Throughout the larval life of these insects (the 'endopterygote' insects) the wing germs grow inwards, and do not become apparent until they are everted at pupation.

The fact remains, however, that the strictly adult structures play no functional part in larval life. Whereas the form of the caterpillar becomes fully differentiated before it hatches from the egg, the adult insect persists in an embryonic state until the growth of the caterpillar is complete and metamorphosis takes place. Indeed, the caterpillar is not a walking embryo, as some authors have contended, but a fully differentiated organism which contains within it, in an embryonic state, the adult butterfly. Metamorphosis consists in the dissolution of the organism of the caterpillar and the simultaneous differentiation and realization of the latent organism of the butterfly which supersedes it.

In the development of animals, the stage of visible differentiation of the parts is preceded by a stage of 'determination,' at which, although all parts outwardly look alike, each is in fact already committed or determined to form some particular component of the organism that is to be produced. Development is then said to have reached the mosaic stage. Determination of the main parts of the insect body occurs very early in the development of the egg. In some insects, the fruit fly *Drosophila* [4] for example, the mosaic state is already attained in the germ plasma on the surface of the egg at the time of laying; that is, before the single nucleus of the egg has even started to divide. In other insects this may not happen until after the germ band has formed. If, when the mosaic state is reached, a part of the determined area is destroyed by burning or by irradiation with ultra-violet light, the corresponding part of the insect will be lacking when visible differentiation and development are complete.

The interesting fact about these insects is that, even at this early stage of development, the larval organism and the adult organism are distinct. Elimination of restricted areas of the newly laid egg of *Drosophila* results in corresponding deficiencies in the resulting larva—but the adult fly, when it appears, is perfectly normal. At this stage the egg is a mosaic in respect of larval characters, but is still undetermined in respect of the adult characters. But within seven hours after laying, imaginal determination has taken place; the egg is now a mosaic in respect of adult characters also, and injuries to restricted areas at this time become apparent in the adult fly. Indeed, if they affect organs, such as legs or wings, that are not present in the larva, the results of these injuries are not visible at all until after metamorphosis. The same thing is seen in the clothes-moth *Tineola* [5]; by irradiation at the appropriate moment it is sometimes possible to obtain a clothes-moth with normal limbs developing from a larva in which one or more legs were completely absent.

Thus, metamorphosis consists in the realization of all those adult or imaginal characters which remain latent throughout larval life; the physiological

FIGURE 1 – Rhodnius *larva in the 4th stage.* (× 4)

FIGURE 2 – Rhodnius *larva in the 5th stage.* (× 3)

FIGURE 3 – Rhodnius *adult with fully developed wings after metamorphosis from the 5th-stage larva.* (× 2·5)

FIGURE 4 – *5th-stage larva of* Rhodnius *still alive more than eleven months after decapitation.* (× 2)

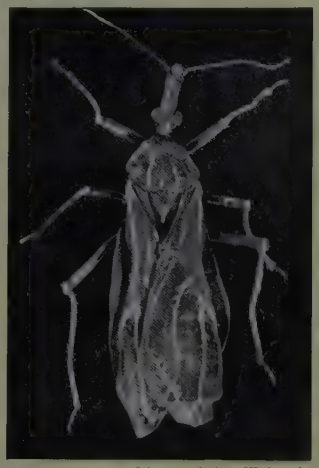


FIGURE 5 – *Giant adult of* Rhodnius *resulting from the metamorphosis of a 6th-stage larva.* (× 2)

FIGURE 6 – *1st-stage* Rhodnius *joined by neck to 5th-stage larva, causing dwarf adult.* (× 3)

FIGURE 7 – *Giant or 6th-stage larva of* Rhodnius *resulting from the implantation of the* corpus allatum *of a young larva (secreting juvenile hormone). The site of implantation appears as a scar on the abdomen.* (× 2·5)

FIGURE 8 – Rhodnius *larva in the 4th stage decapitated one week after feeding, and connected by means of a capillary tube with another 4th-stage larva decapitated twenty-four hours after feeding. The moulting hormone from the first insect causes the second to moult.* (× 3)

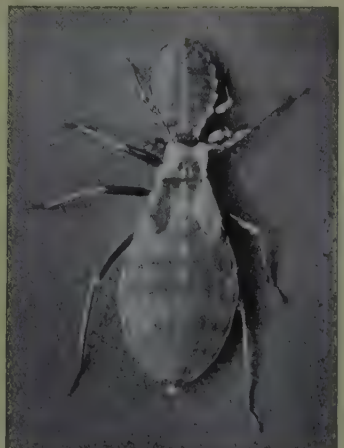
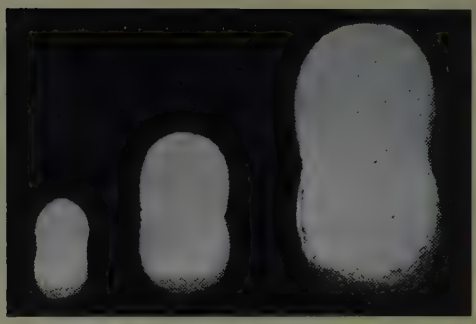


FIGURE 9 – *Young larva of* Triatoma *(above) decapitated twenty-four hours after feeding, and caused to moult by joining it to a 5th-stage larva of* Rhodnius *decapitated ten days after feeding.* (× 3)

(a) (b) (c)

FIGURE 10 – *Pupae of the silkworm:* (a) *from larvae in which the* corpora allata *were extirpated in the third stage;* (b) *from larvae similarly treated in the fourth stage;* (c) *from normal larvae pupating after the fifth stage. (After Fukuda.)* (× 1·5)



(a) (b) (c)

FIGURE 11 – *Cocoons of silk containing the three pupae shown in figure* 10. *(After Fukuda.)* (× 1·3)

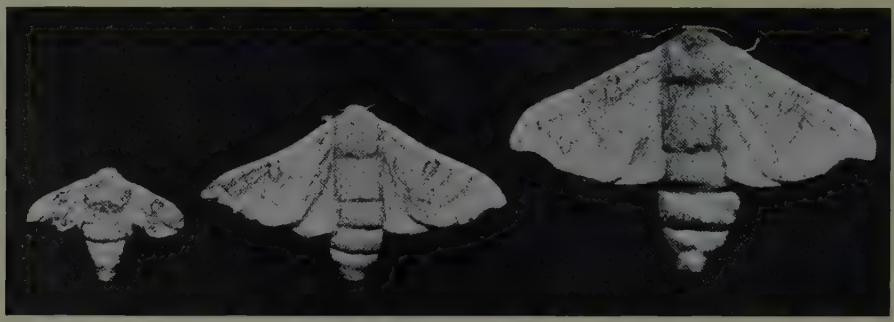
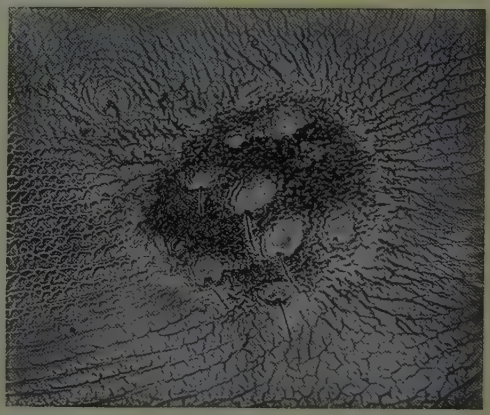


FIGURE 12 – *Silkmoths derived from the three pupae shown in figure* 10. *(After Fukuda.)* (× 1·5)

FIGURE 13 (*left*) – Rhodnius *with characters intermediate between larva and adult produced by implanting* corpus allatum *of young larva into the abdomen of 5th-stage larva* (cf. *figure* 7). (× 3)

FIGURE 14 (*below*) – *Cuticle of the abdomen of an adult* Rhodnius *which had been treated during the 5th stage like the insects shown in figures* 7 *and* 13. *It has turned into a normal adult, but there is a tiny patch of cuticle of larval type, less than* 1 *mm in diameter, overlying the site of implantation of the* corpus allatum. (× 65)



study of metamorphosis consists in the analysis of the factors by which the manifestation of these imaginal characters is controlled.

Many diverse hypotheses have been put forward in the past; but in recent years evidence has accumulated that control is exercised by means of hormones. For the purpose of experiment it proved convenient, in the first instance, to use a hemimetabolic insect; that is, an insect which does not show the extreme degree of transformation from caterpillar to butterfly, but one in which the young stages are not very unlike the adult, and in which metamorphosis consists in the development of wings and genital organs and other structural changes, accomplished without the necessity for an intermediate pupal stage.

The blood-sucking South American bug *Rhodnius*, a creature about two centimetres in length when fully grown, has proved a most useful experimental animal [8, 9, 10, 11]. All insects grow by undergoing a series of moults, during which the epidermis detaches itself from the old cuticle, lays down a new and larger cuticle, and then casts off the old. Like the small bed-bug *Cimex*, *Rhodnius* moults five times; in each of its moulting stages it requires only one gigantic meal of blood. It is at the fifth moult that it undergoes metamorphosis and becomes adult (figures 1–3).

Moulting in *Rhodnius* is preceded by growth, reorganization, and the deposition of the cuticle for the next stage. This whole elaborate process is set in motion by a secretion from certain large modified nerve cells (neurosecretory cells) situated in the dorsal surface of the brain. If the bug is decapitated within one day after its great meal of blood, it fails to moult—although such headless bugs have remained alive for more than a year (figure 4). If, however, the region of the brain containing the secretory cells is transplanted into the abdomen of one of these decapitated insects it will duly moult; and, surprisingly enough, even if it is a young insect at an early stage of development, it will undergo metamorphosis and develop into a diminutive adult. We shall come back to this matter later.

Thus the brain appears to secrete a moulting hormone. In *Rhodnius* this has been supposed to act directly upon the growing organs, but in the caterpillars and chrysalides of moths the process is more complicated. The pupal brain of the silkmoth [13] contains two groups of cells, apparently producing two different secretions, both of which must be present if moulting is to occur. These secretions do not act directly upon the tissues but upon another secretory organ, the prothoracic gland, which in turn produces the secretion that is necessary for growth and moulting. The nature of these substances is not known. There are demonstrable changes in the blood of insects at the time of moulting and pupation, e.g. increases in the amounts of cytochrome oxidase and cytochrome C in the pupae of the large silkmoths [13], and the activation of tyrosinase in the blood of pupating larvae of blowflies [2]. Whether any of these substances is to be identified with the hormone itself, or whether they are merely to be counted among the consequences of its activity, remains to be decided.

The implantation of the cells of the brain, which produce the moulting hormone, into the abdomen of the decapitated *Rhodnius*, results, as we have seen, in the occurrence of metamorphosis —even in the young insect whose growth is far from complete. This result suggests that the head produces a second factor which normally prevents metamorphosis in the young stages. That such a factor exists has been proved. It has been termed the juvenile hormone, and it is secreted by a special gland of internal secretion named the *corpus allatum*. The *corpus allatum* lies just behind the brain; it shows some remarkable resemblances to the glandular part of the pituitary gland in mammals.

Rhodnius, as we have seen, has five larval stages before it becomes adult. If the *corpus allatum* is removed from one of the young stages and implanted into the abdomen of a fifth-stage larva, when this moults it turns into a giant or sixth-stage larva instead of undergoing metamorphosis to an adult (figure 7). Even a seventh-stage larva has been produced in this way, and some of the sixth-stage larvae have transformed successfully into giant adults (figure 5, and *cf.* figure 6).

Conversely, removal of the head of a young *Rhodnius* when moulting is just beginning causes the body to undergo a precocious metamorphosis. It has not been possible to remove the *corpus allatum* in the living *Rhodnius* without undue injury to the head and brain. This has, however, proved possible in other insects, and the results obtained in *Rhodnius* have been amply confirmed. Stick-insects, *Dixippus* [6], treated in this way begin to lay eggs while still quite small. Cockroaches [7] become prematurely adult. Silkworms [1, 3] turn into tiny pupae which give rise to tiny moths (figures 10–12).

The juvenile hormone is secreted throughout the first four larval stages of *Rhodnius*. During

the fifth stage it is no longer secreted; the *corpus allatum* of the fifth stage implanted into the abdomen of another fifth stage does not prevent metamorphosis. In the adult insect, however, this hormone is once more produced. Here it is necessary for the ripening of the eggs. If the adult female is decapitated after feeding, no eggs are developed; they are developed normally if the *corpus allatum* is implanted in the abdomen. If the *corpus allatum* of the mature adult is transferred to the abdomen of the fifth-stage larva, metamorphosis is prevented and a sixth stage is produced.

It is evident that these hormones serve only to control the manifestation of characters that are latent within the cells. It is therefore not surprising to find that they are not limited in their action to the insect species from which they have been derived. The blood of a moulting *Rhodnius* will induce moulting in a decapitated nymph of the related genus *Triatoma* (figure 9, and *cf.* figure 8), or even in the bed-bug *Cimex*. The fifth-stage larva of the bed-bug can be prevented from becoming adult if it is transfused with blood from a young larva of *Rhodnius* containing the juvenile hormone.

Normal development of an insect, with the restraint of metamorphosis until growth is complete, and then, at the appropriate moment, the activation of imaginal differentiation, clearly demands a very nice timing of events. The hormones must be released at the correct time and in the correct amounts. If these conditions are not satisfied, as may happen, for example, in some experiments when a *corpus allatum* from a young *Rhodnius* is transplanted into a fifth-stage larva, and the amount of juvenile hormone present is too small or is produced too late, metamorphosis is incomplete, and creatures intermediate between larvae and adults are produced (figures 13, 14). Errors of this kind are not uncommon in nature. Caterpillars with wing lobes and antennae like half-formed pupae may occur; or pupae may have parts of the body resembling larvae. Such abnormalities are most liable to appear in hybrids resulting from the crossing of different species. There can be little doubt that they result from errors in the timing or the concentration of hormone secretions.

It would seem that the cells of the young insect contain two systems, one capable of producing the adult insect, the other producing the larval insect. In the presence of the moulting hormone alone, the adult system is activated and metamorphosis occurs. In the presence of both moulting hormone and juvenile hormone, the larval system is activated and metamorphosis is suppressed. Or perhaps we have to do with a single system whose activities are modified in alternative directions depending on the presence or absence of the juvenile hormone. In the last analysis, the nature of the constituent elements, and the mode of interaction between the hormones and the potential organism latent in the tissue cells, are biochemical problems. For the moment we can define them only in biological terms.

Once the insect has reached the adult state it does not moult again, save in the most primitive forms. The adult *Rhodnius* can be induced to do so if it is joined to a young moulting insect so that the blood flows from one to the other. If at the same time it is provided with a supply of juvenile hormone by the implantation of *corpora allata*, it develops on its abdomen a type of cuticle which shows unmistakable larval characters. There has been a partial reversal of metamorphosis, a partial recovery of youth.

The future of this subject clearly lies with the chemist. It should not prove an insuperable task to discover the nature of the growth-controlling hormones of insects, and to define the conditions of their action. To discover the nature of the substrate upon which they act, the integrated germ of the organism carried by the living cells [12], is a problem that touches upon the nature of life itself, and may well tax the ingenuity of the biochemist for some time to come.

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The transfer of antibodies across the placenta

R. M. CALMAN and JOHN MURRAY

The reality of the transfer of antibodies from mother to foetus has been recognized for nearly half a century; it plays a decisive role in certain very serious diseases peculiar to newborn infants. The mechanism by which it is effected was, however, obscure, because it is clearly not simple diffusion. In this article the authors discuss the hypothesis that the antibody is not transferred complete and that there are other routes than direct transmission through the placenta. Ingenious diagrams illustrate methods of transfer suggested in the text.

The animal organism, in order to withstand the invading forces of nature, has the power to mobilize its defences to combat the introduction of substances foreign to its tissues. One of the mechanisms by which this is contrived is the creation of particular globulins[1] called antibodies, specific for such foreign materials. Any substance is said to be antigenic if on injection into an animal it calls forth in that animal the formation of antibodies. This is an immune response, and is the well-known principle which forms the basis of immunology. It is upon the natural immunity derived from contact with minimal doses of infective materials that the animal in the wild is able to build up a resistance to disease.

It has long been recognized that the infant derives from its mother some degree of immunity to certain diseases, which appears to be passive in nature; that is to say, it tends to disappear comparatively rapidly in the same way as does passive immunity in the adult, in contrast to the relatively permanent active immunity produced by stimulation of the individual's own tissues.

The origin of this immunity varies in the different species of mammals. In some it is obtained through the colostrum after birth, whereas in others it is obtained *in utero*.

TABLE I

Species	In utero	Via *colostrum*
Man	+	−
Rats and mice	+	+
Other rodents	+	−
Ungulates	−	+

[1] For brevity, when the word globulin is used in the text and diagrams in relation to antibody, it should be understood that the gamma globulin fraction only is intended.

It is with this latter group, which includes humans, that we are at present concerned.

The earliest attempts to tackle the problem of placental transmission are those recorded by Cowper, who in 1698 passed metallic mercury into the maternal circulation and was able to demonstrate globules of the metal in the foetal circulation. These transfers were subsequently shown to be due to rupture of placental capillaries.

It was not, however, until the late nineteenth century, as a result of the discoveries of Ehrlich and others on antibodies, that workers turned their attention to the problems of naturally occurring immunity in the newborn. Shortly afterwards, von Behring and his colleagues expressed the view that antibodies would pass the placental barrier only if it had been previously damaged. It was thought that the passage of antibodies through the placenta was impossible, on account of their relatively great molecular size and the difficulty with which they diffused through membranes.

This idea received great support in 1902 from the work of Ascoli, who showed that foreign proteins did not pass the placenta. The results described by Lochead [1] from Edinburgh in 1907, however, were not entirely confirmatory. He injected egg albumin into the veins of pregnant rabbits and found this substance in the foetal blood, as tested by a precipitin technique; ox serum, however, was not transferred under similar conditions. He concluded from his experiments that the mechanism of placental transmission was similar to the secretion of ductless glands, and that it was not a question of a simple filtration, but a process involving the special functions of a living cell.

These results would require confirmation, but his conclusion should be reconsidered in view of the very recent work of Brambell.

From this point, the picture has been largely coloured by the filtration hypothesis. The papers of Halben and Landsteiner, Schumacher, Römer and Polano [2], together with the studies of Grosser, are all influenced by this view. It is interesting that Polano in his detailed review of the subject in 1904 showed the transfer of passive immunity from mother to child. For these experiments he used tetanus antitoxin prepared in the horse. This, in the light of more recent work, introduced a complication.

The careful anatomical work of Grosser [3, 4] separated placentae of animals into groups according to the number of cell layers dividing the maternal and foetal circulation.

TABLE II

Placental types	*Species*
Pl. epithelio chorialis ..	Pig Horse
Pl. syndesmo chorialis ..	Ruminants (in part)
Pl. endothelio chorialis ..	Beasts of prey
Pl. haemo chorialis ..	Rodents Insectivores (in part) Bats (in part) Apes Man

It was a natural conclusion that these differences between the placentae in the various species might be correlated with the differences in placental permeability to substances of varying molecular size. This work was vigorously pursued by Shimidzu, who classified placental transmission of dyes in terms of their diffusibility in gelatine.

The filtration hypothesis demanded that passage of substances across the placenta should be governed by simple diffusion and osmosis. This was first disputed by Rivkin, who, in a personal communication quoted by Needham [5], suggested that while the bloods must be isotonic, they need not be homotonic.

Needham, in his work on chemical embryology, reviewed the literature of placental transmission and tabulated the results. The table was designed to show the relationship between molecular size and the anatomical barrier. He upholds the views of Rivkin, quoted above, and contends that the importance of Grosser's work was neglected by Wislocki, who thinks that the anatomical differences are of less importance than physiological ones. Needham's table unfortunately appears in some cases to rest on work which is now open to question.

Table III includes only those authors who have recorded the relative levels of antibodies in the human mother and child.

Among the many other workers who have described transmission of antibodies, Debré, Ramon, *et al.* (1930) reported six cases where the mother was passively immunized against tetanus, in five of which they were able to find the antibody in the child; on the whole, the level was lower than in the mother. Their paper was of further interest in that they demonstrated antitoxin in the colostrum in the same five cases.

As will be seen from Table III, later workers, such as Liebling and Schmitz [6], and Bryce and Burnet, report higher levels for diphtheria and staphylococcal antitoxins respectively, but did not attach significance to these results. In fact, one is left with the impression that higher levels of antibody in the cord blood were regarded with scepticism by the authors themselves, because they could not be fitted into the current hypothesis.

At this point it is interesting to note that many

TABLE III

Author	*Antibody level*	*Antibody used*
Polano	(1904) Infant less than mother	Diphtheria
Polano	(1904) Infant less than mother	Tetanus
Stäubli	(1903) Infant less than mother	Typhoid
Schumacher	(1901) Infant less than mother	Typhoid
Wohlgemuth and Massone	(1911) Infant less than mother	Staphylococcal
Ten Broeck and Bauer	(1923) Infant equal to mother	Tetanus
Etienne	(1899) Infant higher than mother	Typhoid
Liebling and Schmitz	(1943) Infant often higher than mother ..	Diphtheria
Bryce and Burnet	(1932) Infant often higher than mother ..	Staphylococcal
Barr, Glenny, and Randall	(1949) Infant often higher than mother ..	Diphtheria
Murray, Calman, and Lepine	(1950) Infant often higher than mother ..	Staphylococcal

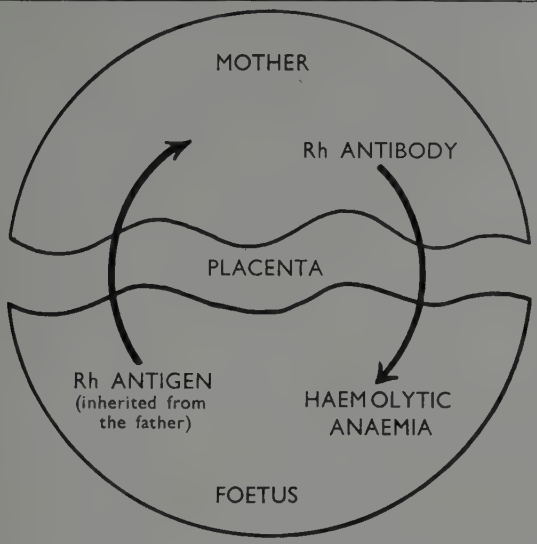

FIGURE 1 – *Illustration of the way in which iso-immunization occurs in pregnancy.*

of these workers reported the presence of appreciable quantities of antitoxin in the amniotic fluid. We have ourselves confirmed this finding in the case of staphylococcal antihaemolysin in a series of unpublished experiments. The significance of these observations will be described later, in relation to the work of Brambell and his colleagues.

The simple filtration hypothesis has been further disputed by Timmerman (1931), who demonstrated a difference in the passage of typhoid O and H agglutinins from mother to child. He found that the H agglutinin passed the placenta in a considerable number of cases, whereas the O agglutinin was scarcely transmitted at all. He took the view that these results showed a selective mechanism dependent upon the living cell. In the same communication he also reported that the O agglutinins were concentrated more strongly than the H agglutinins in the colostrum.

For some years before the second world war, unusual antibodies had been found in the sera of multiparous women. These antibodies were capable of agglutinating the erythrocytes of many people, including those of the husbands, without any relation to the accepted Landsteiner blood-group system. The discovery of the Rhesus factor in 1940 by Landsteiner and Wiener [7] in their search for further blood-group antigens enabled Levine [8] and his colleagues in 1941 to link the findings of unusual maternal antibodies with the Rh factor, and to identify the cause of haemolytic disease of the newborn.

These workers found in over 90 per cent. of cases that iso-immunization to the Rh factor was responsible for this disease, which covers a wide range of clinical appearances, dependent upon the severity of the disease. Thus, mildly affected babies show only slight anaemia, moderate cases a severe anaemia and perhaps marked jaundice, while more severe cases may die at birth or be stillborn. In the extreme manifestations of the disease, the foetus may even die during the second half of its intra-uterine life.

The mechanism by which this disease occurs is demonstrated diagrammatically in figure 1, where the foetus is shown to inherit the offending antigen from the father. The mode of inheritance has been proved to fit Mendelian principles. It can be seen from the accompanying figure that the complete cycle of the disease depends upon foetal antigen reaching the mother, and maternal antibody reaching the foetus.

During the ensuing years it has been shown that almost all cases of haemolytic disease of the foetus in the human are caused by Rh immunization. There is, however, not just one Rh antigen, but a complicated system of Rh antigens, all of which are antigenic for those who lack them. Discoveries in this field followed rapidly one upon the other in a spate of writings, so that R. A. Fisher [9] in 1944 was able to synthesize the findings of the Cambridge workers into a remarkable genetical scheme. The scheme proposed was all the more remarkable since at that time it postulated the existence of genes as yet undiscovered. All Fisher's postulates have since been verified experimentally.

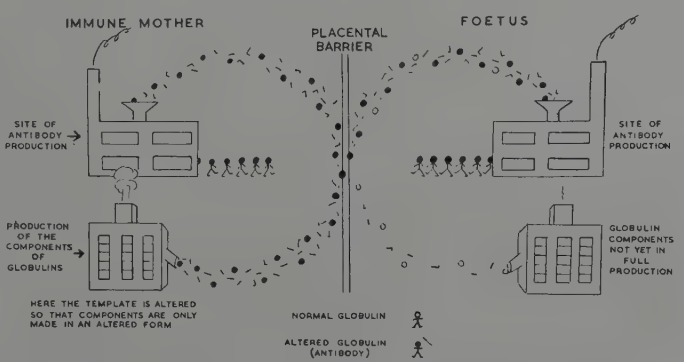

FIGURE 2 – *This diagram illustrates the hypothesis for the production and transfer of antibodies from mother to foetus.*

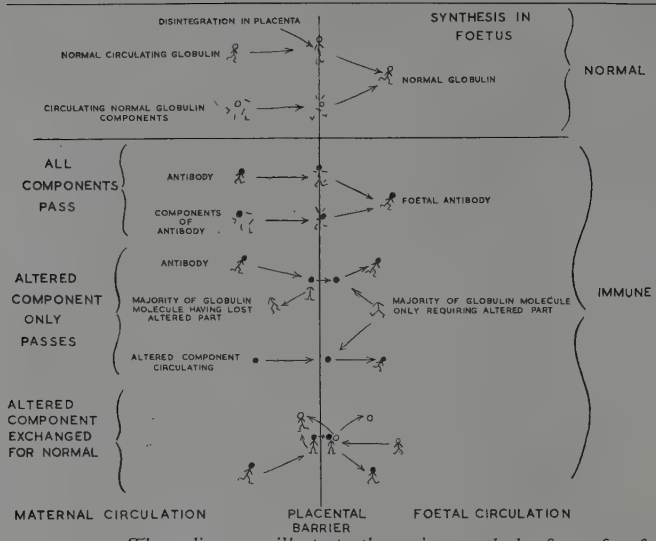

FIGURE 3 – *These diagrams illustrate the various methods of transfer of normal and immune globulins suggested in the text.*

It has been shown repeatedly that relatively small quantities of blood are necessary to immunize both humans and rabbits, and Levine has suggested that foetal red cells escape from the placenta in pregnancy in sufficient numbers to stimulate antibody production if they contain incompatible Rh antigens. He was able to immunize rabbits with fourteen minute daily injections of blood, equivalent to 0·0672 c.c. of blood cells for a 120 lb woman.

It is difficult to accept this theory for every pregnancy, since haemolytic disease is relatively rare. To explain this, Haldane put forward the possibility that permeability of the placenta is controlled by an extra gene, but there are no facts to support his contention.

It is possible that sufficient foetal Rh antigen, contained either in whole erythrocytes or in the products of cell disintegration, does enter the maternal circulation to enhance antibodies already present. One of us has suggested that this is the case, but that the whole process has to be initiated by sudden exposure to a large dose of the antigen in question—either by transfusion, whole blood injections, rupture of placental vessels, or massive infarction of the placenta.

It appears unlikely for a woman to have obtained her initial immunizing dose while she was a foetus herself, although this could be considered a theoretical possibility in those cases where the position is reversed, and there is an Rh positive mother of an Rh negative female foetus. Such experiments as we have done have tended to disprove this idea.

Haemolytic disease of the newborn had been observed for a long time in domestic animals, but the first serological proof of the cause being iso-immunization of pregnancy was produced by Caroli and Bessis (1947). These authors demonstrated the condition in mules. At the same time, Coombs [10] and his colleagues at Cambridge (1948) were investigating iso-immunization among racehorses at Newmarket. In the same year, confirmation of haemolytic disease came from Bruner *et al.* in America, where they also described the same disease in piglets. Haemolytic disease has also been described in dogs by Eyquem, Young *et al.*, and Abelson.

In all these animals the disease arises after suckling, and it appears that the damaging antibody is obtained by the infant through the colostrum.

In mating experiments, using Nachtsheim's strain, Coombs [10] and his colleagues [11] tried unsuccessfully to reproduce haemolytic disease in rabbits. These Cambridge workers therefore attempted to induce experimental iso-immunization in rabbits. They were successful in creating antibodies in does by injecting them with the blood of the bucks to which they had been mated. Moreover it was possible to demonstrate that maternal antibodies had crossed to the foetus, because the blood cells of the baby rabbits had antibody attached. It was remarkable, however, that although the baby rabbits received the antibodies which were attached to the cells, no clinical or haematological effects could be observed, and the baby rabbits remained healthy. However, these authors are not sure whether the antibody passed to the baby *via* the placenta, or the colostrum, or both. Similar experiments in guinea-pigs were unsuccessful.

The study of haemolytic disease in animals other than man leads us to conclude that with horses and mules the dam can become immunized to a foetal antigen inherited from the sire, but that no disease occurs in the foal during pregnancy. It is not until the foal has access to colostrum that it becomes a victim of the maternal antibody. On the other hand, it appears unlikely that haemolytic disease can be caused in rodents at all. Firstly, immunization of the female has not

been shown to occur naturally, and secondly, even when artificially induced, it does not cause disease in the litter, although the antibody can be shown to reach the infant.

As yet, the nature of Rh substances is unknown, and although Rh haptens, the specific parts of the antigens, are said to have been isolated in America in lipid fractions of blood-cell extracts, it has been impossible in these and other laboratories to corroborate the findings.

Blood cells are not the only ones to contain this Rh antigen, for Boorman and Dodd (1943) were able to demonstrate its presence in many other organs by an inhibition technique. The presence of Rh antigen in brain tissues was demonstrated by Dereymaeker (1949), in placental tissues by Von Bolhuis (1948), and in solution in amniotic fluids by Witebsky and Mohn (1945).

Placental transmission has often been used as synonymous with transmission from mother to foetus; this unfortunately is not necessarily true. In the case of the rabbit, the work of Brambell *et al.* [12–14] has shown that in fact the transmission is by way of the yolk-sac splanchnopleur (one of the foetal membranes), and that the placenta is impassable to the agglutinins (*Br. Abortus*) used.

It shows also that the lumen of the non-gravid uterus may contain antibodies; that antibodies can pass from the uterine lumen to the embryo; and that for this to occur, the integrity of the yolk-sac circulation is essential. The antibody titres obtained were not correlated with the maternal titre, and these authors consider that the total amount passed may be limited by factors other than the strength of circulating maternal antibody.

They have recently demonstrated that the yolk-sac splanchnopleur of the 24-day rabbit embryo will pass antibodies prepared in the rabbit, but will only to a very limited extent pass antibodies prepared in cattle or horses. This selectivity is developed from the 20th to 24th day, and the time of development of this property is well defined. They have further shown that the selectivity is independent of molecular size. This they did by using rabbit agglutinins and haemolysins, and bovine and equine agglutinins and antitoxins. The rabbit bacterioagglutinins have relatively small molecular size, while those of cattle and horses are large. The haemolysins of rabbits immunized against sheep red cells, however, belong to the group of antibodies of large particle size. The rabbit antibodies were always admitted, whereas the equine and bovine antibodies of similar molecular size were partially held back or totally excluded. Where the yolk-sac splanchnopleur was exposed to a mixture of sera, there was no evidence of interference, and the selection did not appear to be influenced by the total mass of the molecules.

The theoretical views put forward at the conclusion of their paper suggest that the selectivity of the foetal splanchnopleur is due to cellular phenomena. They postulate that foreign antibodies are either fixed or excluded by the membranes, whereas homologous antibodies pass into the membrane and are subsequently released.

When we are considering the passage of antibody from mother to child, we find that some types of antibody are transmitted well, and others poorly if at all. Different sorts of Rh antibodies are recognized according to whether or not they clump appropriate red cells in saline. The types of Rh antibody which do not clump cells in saline may do so in protein media, and all can be demonstrated by their property of 'sensitizing' erythrocytes. The method used for the detection of 'sensitized' cells is that devised by Coombs [15]. These antibodies are reported to have different properties with regard to transmission from mother to child. Thus the 'incomplete' or sensitizing antibodies reach the infant's circulation, while the simple 'saline-acting' agglutinins do not. This is an interesting observation in view of the findings of Timmerman already described, where typhoid H agglutinins pass readily but O do not.

We consider it is a tempting hypothesis that the mechanism by which antibodies reach the foetal circulation may involve the breakdown of the complex molecule of antibody into its constituent parts, and that these pass across the placenta to be re-formed into antibody on the foetal side. This might require the existence of a specific group or arrangement of groups for each antibody which would pass unchanged through the placental epithelium. Conceivably such groups might be only minute fractions of the complete antibody globulins. The hypothesis put forward by Brambell requires the passage into the cells of large protein molecules, but does not explain how this comes about. It may be that the penetration of the cell is in itself accompanied by degradation and resynthesis before the homologous antibodies are released. This would, of course, explain the selectivity observed, since the recombination of proteins foreign to the species would be unlikely. On the other hand, the small specific groups which we have suggested would have much less difficulty in passing into such a cellular barrier than whole globulins.

To satisfy our hypothesis, there are two principal ways in which the immune globulin could be manufactured for the foetal circulation:

1. The maternal antibody may arrive at the placental barrier in its constituent parts or may be broken down by the cells, to be resynthesized either at the foetal surface or at a distance.
2. The specific grouping alone may pass across, and be resynthesized either at the foetal surface, or at a distance, with the remainder of the globulin derived from the foetus. These are illustrated diagrammatically in figures 2 and 3.

The difference between the alternatives is that, in the first case, the antibody is reconstituted from materials entirely derived from the maternal side, whereas, in the second, the foetal tissues must synthesize the majority of the globulin molecules, requiring only the special grouping from the maternal circulation.

Mechanisms of this type render it easier to understand the fact that we and others have demonstrated higher levels of antitoxin in the foetus than the mother. Also they would allow for the high values of gamma globulin found in cord bloods by Longsworth *et al.* (1945) [16]. It may be significant that it was the gamma fraction only which these authors found so high.

We have not discussed the method by which antigenic material reaches the mother from the foetus in iso-immunization of pregnancy. On a hypothesis analogous to that which assumes antibodies to reach the child by a process of disintegration and resynthesis, Coombs has suggested that antigens may be degraded and recoupled to maternal protein in certain individuals after passing the placenta, and so become antigenic once more.

The clue to an alternative route for the passage of immunity to the foetus may lie in the observation that amniotic fluid contains appreciable quantities of antibodies. Since it is accepted that this fluid passes through the mouth into the gut, it is possible that the foetus may obtain immunity in this way during intra-uterine life; the experiments of Potter and others have demonstrated the absorption of amniotic fluid through the lungs and gut as early as the twelfth week of pregnancy. This method would, of course, be analogous to the absorption of antibodies from colostrum in sheep, horses, and other animals after birth.

To sum up, it appears to us uncertain to what extent placental transmission is used in the transfer of antibodies to the foetus. The evidence suggests that in any one species the various methods—by placenta, by foetal membranes, by colostrum, and perhaps by amniotic fluid—may each play a part, and only the amount which each route contributes may vary with the species. Whichever method is used, it appears to us likely that the whole antibody does not pass over unchanged, but that it may only be necessary for a small specific fraction of the gamma globulin to reach the foetal circulation, and that the antibody is completed on the foetal side.

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Sex in the honey-bee

ANN R. SANDERSON and D. W. HALL

About 100 years ago the great bee-master Johann Dzierzon (1845) first advanced some convincing experimental evidence that drones of the honey-bee arise from unfertilized eggs; he thus started a lively controversy which lasted for over fifty years. That parthenogenesis or virgin birth occurs in the bee is accepted today as an undisputed fact, and drones are considered to be haploid individuals. Relation between sex and size is still obscure.

Cytological investigation of the honey-bee, begun by von Siebold (1854) and continued by Blochman (1889), Petrunkewitsch (1901), Meves (1907), Nachtsheim (1913), and others, has established that the unfertilized egg which develops into a drone possesses only half the number of chromosomes of the fertilized egg. On the maturation of the sperms, the usual halving of chromosome number does not take place, since the cells already contain the reduced or haploid number. The females—queens and workers—arise from fertilized eggs and contain the diploid number of chromosomes, i.e. a haploid set derived from the egg nucleus and a haploid set from the fertilizing sperm nucleus. The diploid eggs developed within the female undergo a reduction from diploid to haploid immediately after they are laid. If unfertilized, they contain the haploid number and develop into drones; if fertilized by a haploid sperm they contain the diploid number and develop into females.

In certain Hymenoptera, e.g. some saw-flies and gall-flies, males are unknown or exceedingly rare, and the eggs, being of necessity unfertilized, yield not males, as in the bee, but females. This type of parthenogenesis is known as thelytoky, and diploidy is maintained from generation to generation either by non-reduction during maturation (*Thrinax macula* [18]) or by temporary reduction followed by a restoration of the diploid number (*Pristiphora pallipes* [4]). (See page 34.)

LAYING WORKERS

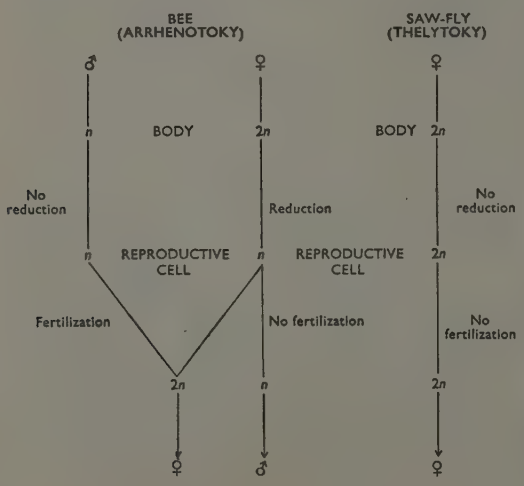
In the bees, wasps, and ants, however, parthenogenesis is apparently almost exclusively of the arrhenotokous type, that is male-producing, but from time to time bee-keepers report that worker bees, presumably virgin, give rise to female offspring. The worker larva normally has about 30 egg-tubes per ovary (a queen has about 200; see figure 1*d*), but they begin to degenerate before pupal life, and in the adult only from 2 to 12 tubes are recognizable (figure 1*a*), so that the normal worker is a female with degenerate ovaries. The spermatheca is rudimentary, and is incapable of receiving or storing sperm even if the genitalia would allow of insemination. Workers can produce eggs under special conditions, but such laying workers occur very rarely in well-managed apiaries. If for any reason the queen fails to lay, or is producing only drones, or if the colony becomes queenless and remains so for a time, the ovary in some of the workers may regenerate (figures 1*b* and 1*c*). Our recent examination of an imperfect hive revealed that about 80 per cent. of the workers had well-developed ovaries, some with mature eggs; the spermatheca in a few cases was enlarged, but was never as large as in a queen. Sperms are never found in smears of the contents of the spermathecae of workers, and thus the laying worker of the honey-bee cannot lay fertilized eggs. Hence it is generally believed that any eggs of a laying worker which develop can produce only drone offspring. Nevertheless, in a South African race, *Apis mellifica unicolor* var. *intermissa*, it has been reported by Onions and confirmed by Jack [11] that worker eggs develop into queens as readily as fertilized eggs of mated queens. Parthenogenetic development of females among Syrian and Tunisian bees also takes place, and has been reported among Italian bees [12].

CHROMOSOMES AND GENES

Recent work on the cytology of the honey-bee [20] has confirmed that in the drone there are 16 chromosomes in all stages of the developing sperm—in spermatogonia, spermatocytes, and spermatids. In the queen, there are 32 chromosomes in the oogonia and 16 in the reduced oocyte and polar nuclei (figures 2*b* and 2*c*). The smear or squash technique is invaluable in determining chromosome numbers. Aceto-orceïn preparations show the chromosomes somewhat distended, but cell boundaries are clear-cut, and spindle fibres—

or at least the outline of spindles—can readily be distinguished. Thus fairly accurate counts within individual cells can be made if nuclei are actively dividing. These chromosomes are not associated in pairs, as erroneously reported by previous workers [15], and, although small, they yet show a certain amount of individuality. One hooked chromosome (figure 2*a*, *h*) in male haploid cells appears to be present in duplicate in female diploid cells.

Since the publication of these results, Manning [13] has claimed to have found what he considers to be a sex chromosome in the honey-bee. This sex chromosome he identifies with the hooked chromosome previously figured by the authors [20]. According to Manning, this chromosome, after dividing to give two chromatids, is lost during the abortive first maturation division, thus leaving only 15 chromosomes in the spermatid. We have not been able to confirm this, although the occasional separation of single chromosomes from the main plate has been observed. In the female, Manning finds only 31 in the oogonia; he considers the unpaired chromosome to be a sex chromosome (15 pairs + X). He states that, during maturation of the egg, the odd unpaired chromosome is probably retained in the female pronucleus, and that the fertilized female-producing egg will therefore contain 31 chromosomes —15 from the male pronucleus and 16 from the female pronucleus. However, photographs and figures submitted in support of his theory of differential maturation are unsatisfactory. Nor does he give any illustration of oogonial plates showing the unpaired so-called sex chromosome.



It may, of course, yet be proved that sex chromosomes do exist in Hymenoptera.

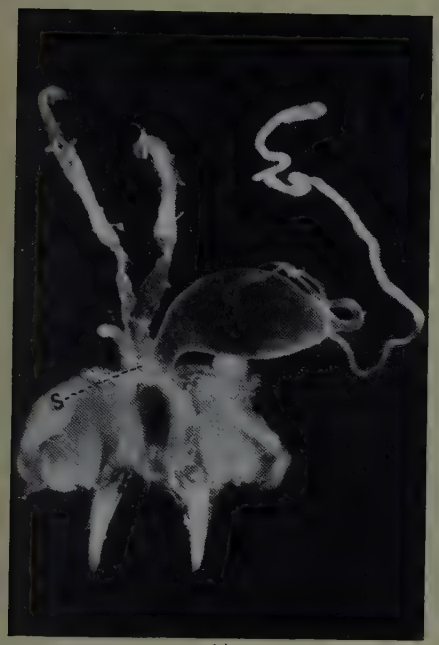
From genetical experiments, Whiting [22] postulates the existence of sex-determining genes in the ichneumon-fly, *Habrobracon juglandis*. They form a series of multiple alleles having similar effects phenotypically, and the approximate location of these sex-differentiating segments has been determined cytologically. The female-determining genes are dominant, and in the heterozygous diploid condition a female results; in the azygous or hemizygous haploid and recessive condition a male results. In the homozygous, double recessive, condition diploid males can be produced, but these are usually inviable. Sex determination is therefore regarded as complementary, and not dependent on genic balance as in non-parthenogenetic types such as the fruit-fly *Drosophila*.

BIPARENTAL MALES

The occurrence of uniparental females in the honey-bee, namely in the South African race, is exceptional, but even more remarkable is the discovery of biparental and diploid males of *Habrobracon* [23,10], a phenomenon unique among Hymenoptera. That they are biparental is shown by the fact that they carry both maternal and paternal characters. That biparental drones occur in the honey-bee is sometimes maintained by bee-keepers, but rigid proof is lacking. In the honey-bee, the mating of the queen is not readily controllable, since copulation takes place in the open, but successful artificial insemination can now be effected [3]. This obviates any doubt as to the paternal origin of characters transmitted to the offspring. Since sperms may remain viable within the spermatheca of the queen for two years, and may even survive after removal and re-injection into a second queen, it should now be possible to obtain closer matings and genetic combinations—for example, father-daughter as well as mother-son matings. By this method, close inbreeding would be ensured, and thus biparental males might be obtained experimentally.

HAPLOIDY AND THE SOMATIC CHROMOSOME NUMBER

Cytological examination reveals that the germ cells in these biparental males of *Habrobracon* are diploid. Their genetical character does not concern us here, but their very existence has led to further investigation of the haplo-diplo relationship of males and females—not only in this particular braconid, but in Hymenoptera in general. Thus,



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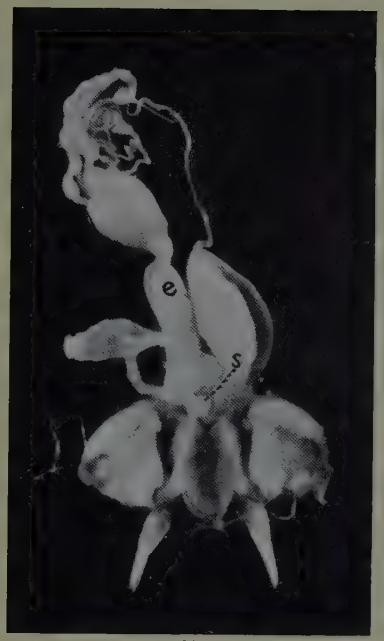

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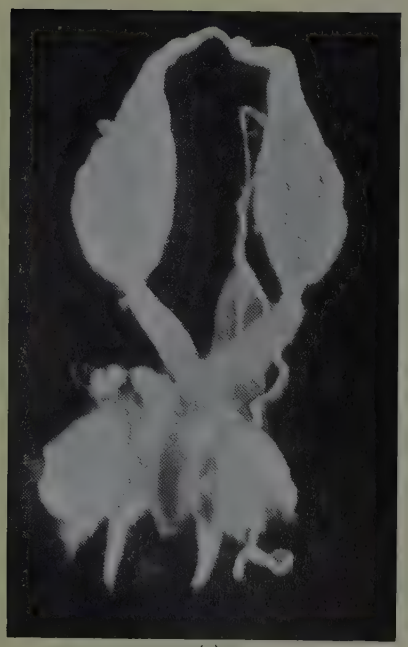

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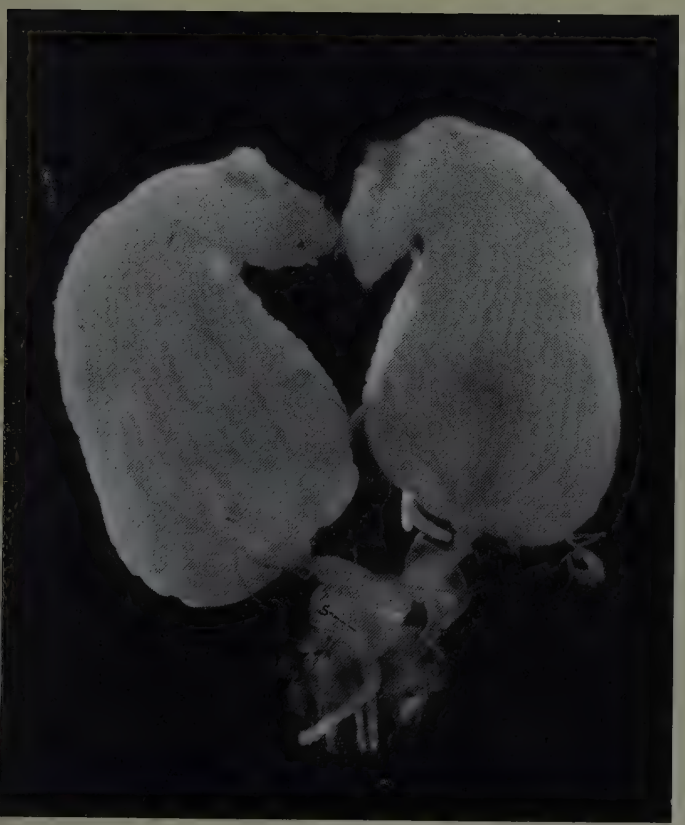
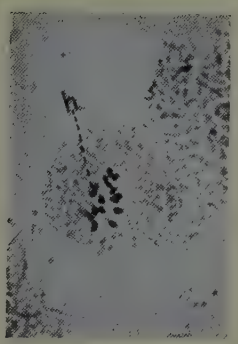


(d)

FIGURE 1 – *Dissection of ovaries and genitalia of queen and worker bees* (Apis mellifica *L.*). (a) *Normal worker, showing rudimentary spermatheca* **s**. (b) *Laying worker, showing ripe egg* **e** *in oviduct and slightly enlarged spermatheca* **s**. *Left ovary cut away.* (c) *Laying worker, showing both ovaries very well developed.* (d) *Normal laying queen, showing very large spermatheca* **s**. ((a), (b), *and* (c) × 3, (d) × 7)



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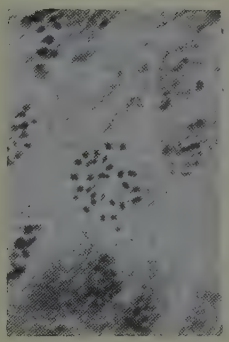

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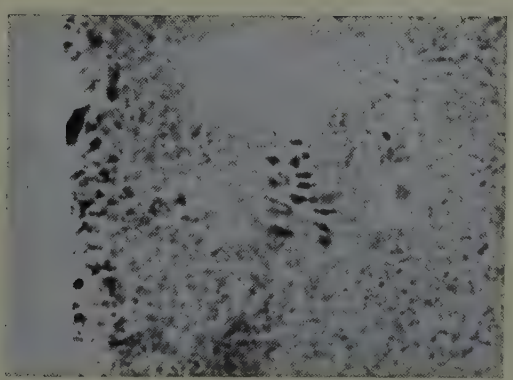

(c)

FIGURE 2 – *Photographs of chromosome plates of* Apis mellifica *L., stained with aceto-orcein.* (a) *Spermatogonial cell with* 16 *chromosomes, showing hooked chromosome* **h**. (b) *Oogonial cell with* 32 *chromosomes.* (c) *Egg maturation, first spindle, showing* 16 *bivalents.* (× 1800)

(a)

(b)

FIGURE 3 – *Photographs showing difference in size in male and female gall-flies and saw-flies.* (a) *Adults of cynipid* Andricus curvator *Htg.—male* below, *female* above (× 10). (b) *Larvae* (*prepupae*) (♀ *left*, ♂ *right*) *of gooseberry saw-fly*, Pteronidea ribesii *Scop., photographed at moult before spinning cocoon, and subsequently dissected in order to verify sex* (× 6).

FIGURE 4 (*below*) – Apis mellifica *L. Drones from laying worker, from worker comb.* (× 2·5)

(*Photographs* 3(b), 4, *and* 5 *by F. L. Waterhouse, M.Sc.*)

FIGURE 5 – Apis mellifica *L.* (a) *Fertile laying queen.* (b) *Normal drones from drone comb.* (× 2·5)

FIGURE 6 – Apis mellifica *L.* (a) *Laying workers, showing dorsal aspect* (left) *and ventral aspect. Note that the abdomen is larger and more keeled than in the normal worker.* (b) *Normal worker in dorsal* (left) *and ventral aspect.* (× 2·5)

today, interest tends to be focused not so much on the maturation of the gametes as upon the chromosome constitution of male and female tissues, both germinal and somatic.

In smear and squash preparations of developing hymenopterous gonads, one can readily obtain chromosome plates with the unreduced or diploid number in the female, and reduced or haploid number in the male (figures 2*a* and 2*b*). Somatic tissues are not so easily investigated. Numerous mitotic divisions yield good counts, but one frequently finds that these plates are polyploid, containing not the expected haploid or diploid sets of chromosomes (genomes) but sometimes three, or, more often, four or eight genomes. Unfortunately, irregularities in chromosome number among somatic cells in both animals and plants are much more common than is generally supposed, and not only in the direction of polyploidy. Berger [1] found that somatic segregation is a regular occurrence in the gut of mosquito larvae, and, more recently, Huskins [9] and his colleagues have found segregation or reduction to the haploid condition (or both) in root tips of the onion.

The haplo-diplo relationship in the bee can be demonstrated readily in the reproductive cells, but not so readily in the somatic cells. Thus, while a developing drone bee has 16 chromosomes in the spermatogonia and spermatocytes, there may be 32 in the follicle epithelial cells of the testis, and 16, 32, 64, or more in developing hypodermal or tracheal cells. Similarly, a developing queen may have 32 in the oogonia and 32, 64, 128, etc., in the ovarian follicle cells or imaginal tissues. If we consider the gonial count as the basic somatic number, the drone is a haploid individual and the female a diploid.

In view of statements such as that of Whiting [22] that 'the diploid drone (of the honey-bee) breeds as a haploid although he produces diploid sperms,' it seems that the time has come for a better definition of what is meant by the terms haploid and diploid organisms. In this article the terms haploid and diploid have been used to describe the condition existing in the primary reproductive cells—haploid where only one genome is present (♂), and diploid where two genomes are present (♀).

HAPLOIDY AND BODY SIZE

It is an obvious fact that, in the non-social Hymenoptera, males are on an average much smaller than females—for example in gall-flies and saw-flies (figures 3*a* and 3*b*). We do not know whether the smaller size of the male individual is due to its having relatively smaller tissue cells than the female, or whether it has a smaller number of normal-sized cells. Comparisons of cell size in arrhenotokous types have been made by Oehninger [16] and Whiting [22]. The latter finds that in the haploid male of *Habrobracon* the cells are almost as large as in the female, while diploid males have larger cells than diploid females. Cell size therefore appears to increase with the number of genomes, but it would seem that maleness itself is an even more effective factor.

In the social insects such as bees, wasps, and ants, the sexual forms do not show any great disparity in size, owing to special feeding during larval life (figures 5*a* and 5*b*). If drones are developed in worker comb, as in the case of offspring of laying workers, they are recognizably smaller than drones from the larger drone cells (figures 4 and 5*b*), thus indicating a quantitative influence by the food. With regard to polymorphism in the honey-bee females, it would appear that nourishment again plays an important part. As already stated, the ovary in the younger worker larva normally has about 30 egg-tubes, but before pupation it has begun to degenerate. If, later, a worker should regenerate the ovaries, so that eggs are produced, the abdomen will appear to be somewhat larger than that of a normal worker (figures 6*a* and 6*b*). Haydak [8], discussing larval food and development of castes, concludes that morphological differences displayed by queen and worker are due to quantitative differences in the food. Queens are given bulk feeding during the whole of their larval life; workers during the first three days only, feeding thereafter being direct from the nurse bees. The size of the worker bee is therefore no criterion for comparison with that of the male, as the worker is a very specialized sterile female. In certain ants, the differences in size between the fertile and sterile castes are even more marked, the workers being extremely small. In the ant *Monomorium pharaonis* L., differences in the fertile and sterile females appear to be due to quantitative differences in feeding (Hall and Smith, unpublished). The haploid male is not much smaller than the diploid queen [17], but one cannot ignore the possibility of the effects of special feeding.

In establishing the haplo-diplo relationship of the soma in the male and female of the honey-bee, where polyploidy is so prevalent, it will be necessary to ascertain that the cells examined for chromosome counts are of comparable generations.

This might be ensured by counting the number of cells in one particular structure—for example, a nerve ganglion, where polyploidy is not so prevalent. Cell sizes could then be compared, and chromosome counts of mitotic cells of the same generation might be obtained in the two sexes.

A new method of investigation has been suggested by recent biochemical researches [5]. In a number of vertebrates which have been examined there is in all somatic cells of the body a measurable amount of a certain nuclear constituent, viz. desoxyribonucleic acid (D.N.A.), and this is constant for any one type. As is to be expected, the D.N.A. value for sperm nuclei is half that of the normal somatic nuclei, since the sperm contains only half the amount of chromatin present in the somatic cell. Having ascertained the D.N.A. constant for any particular species, and the amount per unit of tissue weight, the number of cells present in any sample can be determined. If this method can be successfully applied to insect tissues it may be possible, by a comparison of male and female tissues in parthenogenetic species, to determine whether differences of body size are due to differences in number of cells. The advantage of applying this method would be that the total number of cells could be calculated for the entire insect. It has been shown by Sanderson [19], Miles [14], and Smith [21] that in certain saw-flies which produce males by haploid parthenogenesis, the male larvae in any mixed brood are recognizable by their smaller size. Although cytological observations on saw-flies [19] have suggested that male haploid cells are smaller than comparable female cells, with this new technique it may now be possible to reinvestigate the problem. Although polyploidy most certainly occurs in many tissues, its extent is apparently comparable in both sexes. Thus any inaccuracy in the calculated nucleic acid value per nucleus, due to the presence of a percentage of polyploid cells, would be negligible when comparing the two sexes.

So far we have not considered egg size in dealing with progeny of laying workers and queens. Flanders [6] believes that oosorption takes place when ovulation of the egg is delayed, and that the subsequent loss of nutriment (or egg degeneration) is the basis of polymorphism in certain social Hymenoptera. Although no data are available on the influence of egg volume on the size of resulting embryos in the honey-bee, work of such a nature carried out on frog embryos [2] shows that increased rate of growth gradually compensates for initial smallness.

Thus differences in body size in Hymenoptera may be due to one or all of the following causes: (1) feeding; (2) size and number of tissue cells, correlated with the chromosome complement; (3) initial size of egg.

CONCLUSION

In the authors' opinion male Hymenoptera are to be considered haploid organisms, first because the gonad is definitely haploid in constitution, and secondly because early cleavage and embryonic cells are haploid. The uniparental haploid male is generally markedly smaller than the biparental diploid female. In *Apis mellifica* L. the queen and queen-produced drone appear to owe their increased size to special nourishment, whereas the normal worker is undersized. The drone, whether produced by a queen or a worker, is a haploid individual, and, although the true haplo-diplo size-relationship of male and female is masked by special feeding, the worker-produced drone probably gives a better indication of the natural size of the male.

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The nature of ion exchangers

E. GLUECKAUF

The importance of ion exchangers has increased enormously during the last fifteen years as a result of the development of synthetic materials differing from natural ones in the consistency of their properties, in their very much larger capacity, and in their ability to function under a much wider range of conditions. Apart from their large-scale applications in water-purification processes, the introduction of ion exchangers into chromatography has been of the greatest practical importance, permitting rapid separation of many mixtures of inorganic ions which have long proved intractable by the older classical methods.

It often happens that an almost forgotten phenomenon suddenly rises to the forefront of scientific and technical interest. This happened to the process of column separation by adsorption discovered in 1906 by the Polish biochemist Tswett. After a substantial period of obscurity it slowly developed—first as a means of purification, then as a method of separation—into one of the most powerful tools at the disposal of the chemist for the separation of substances which resist other attempts at isolation.

The phenomenon of ion exchange, now firmly coupled with column separation, has a still older history. Its importance for the chemistry of soils was realized by Way a century ago [1], and among the early studies of its physical basis may be mentioned the work of Rothmund and Kornfeld on the exchange properties of zeolites, a type of alumino-silicate.

It was the discovery by Holmes and Adams in 1935 of synthetic resinous ion exchangers [1], rendering possible the manufacture and, one might almost say, the design of ion exchangers of reproducible and well-defined properties, which raised the status of ion exchange to that of an important technique, the applications of which now pervade an ever-growing field of science and industry. Nowadays we cannot open a scientific or technical journal without being reminded of its almost universal applications: separation of organic bases, of amino acids, of isotopes; treatment of blood; purification of sugar; demineralizing of oils; production of pure rare earths; and preparation of conductivity water.

TYPES OF ION EXCHANGER

The resins used are generally produced by a polymerization process such as the condensation of polyhydric phenols with formaldehyde, or they may be polystyrene-like substances cross-linked by the addition of varying amounts of divinylbenzene (see figure 1). The exchanging groups may be introduced either before or after condensation.

Cation exchangers. These are resins which embody acid groups such as $—SO_3H$, $—CO_2H$, or phenolic —OH. While the first type behaves like a strong acid and consequently exchanges its hydrogen equally well at all *p*H values, the carboxylic resins can be used only at medium to high *p*H, because the hydrogen in the only moderately dissociated $—CO_2H$ group is difficult to replace by other ions if the surrounding solution contains excess hydrogen ions as well. This is still more so in the case of —OH groups, which, like those in simple phenols, give up their hydrogen only in quite alkaline solution. However, while a sulphonate exchanger is obviously required for use in acid solutions, the carboxylic resins are not without advantages in neutral solutions, as not only is their capacity very high (up to 10·5 equivalents per kg as compared with 4·8 for the best sulphonates), but they are frequently more selective in their exchange properties.

A new type of resin which may have a great many uses is being evolved in the 'chelating' resins [2]. These are extremely selective for elements of the transition groups.

Anion exchangers. Just as resins with acid groups act as cation exchangers, those with amino groups in their structure can act as adsorbers or exchangers of anions. While the amino groups of the earlier anion exchangers were only weakly basic, and would not adsorb anions in alkaline solution, the more recently developed exchangers utilize substituted amino groups such as

$$—N(CH_3)_3^+,\ —N(CH_3)_2(CH_2C_6H_5)^+,$$

and $—N(CH_3)(CH_2C_6H_5)_2^+$

which are more basic in character. The last type of resin is so strongly basic that any sodium salt

solution passing through a column of it will emerge as pure sodium hydroxide solution.

Both cation and anion exchangers can be made in a variety of forms, e.g. granular and spherical, and a number of them also as rods, plates, and membranes. Their physico-chemical properties can be considerably altered by variation of the starting materials and of the degree of cross-linking of the monomer chains.

PHYSICAL CHEMISTRY OF ION EXCHANGERS

Distribution equilibria. An important feature of the ion exchanger is its ability to differentiate between the various ions, that is, to show preference of adsorption to one kind as compared with another. This property is defined by the separation factor k_s:

$$k_s = \frac{X_2 c_1}{X_1 c_2} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

where X_2/X_1 is the ratio of the molar fractions of the two ions I and II in the resin phase, in equilibrium with the corresponding concentrations c_1 and c_2 in the aqueous phase. This factor need not be constant under varying conditions; it may for example depend on the total concentration of the aqueous solution, or on the ratio X_2/X_1, or on the presence of a third solute. In order that two solutes should be easily separable, k_s should differ as much as possible from unity. k_s is an important parameter in the equations derived in the theory of chromatographic column separation. The greater its difference from unity, the shorter can be the column required for the separation of a given quantity of material, the faster can be the rate of flow through the column, and the sharper will be the boundary between different zones of components. Naturally, therefore, a great deal of research [3, 4, 5] has been directed towards the determination of separation factors for different ions.

Generally speaking, the affinity of the exchanger for an ion increases with the ionic charge of the latter: thus $Th^{4+} > Al^{3+} > Ca^{2+} > Na^{+}$. Within a given valency type, one has a considerable choice in expressing the order—the affinity goes with increasing atomic mass, or with increasing volume of the unhydrated ion, or with decreasing radius of the hydrated ion—but whatever the explanation, the order is usually: Cs > Rb > K > Na > Li, and Ba > Sr > Ca > Mg > Be, and La > Al. The group NH_4^+ behaves rather like potassium, being usually slightly more strongly adsorbed. The position of the hydrogen ion varies for different types of exchanger. For weakly acid exchangers, e.g. those containing carboxyl groups, it is the most strongly adsorbed univalent ion and is probably covalently bound; whereas for strongly acidic exchangers containing sulphonate groups its affinity falls between those of Li and Na, and is usually nearer to the former, so it is presumably contained in the resin as a hydrated ion.

The affinity for substituted ammonium ions increases with their size. $NH_4^+ < (NH_3CH_3)^+ < NH_2(CH_3)_2^+ < N(CH_3)_4^+ < N(C_2H_5)_4^+$, though a limit is reached owing to

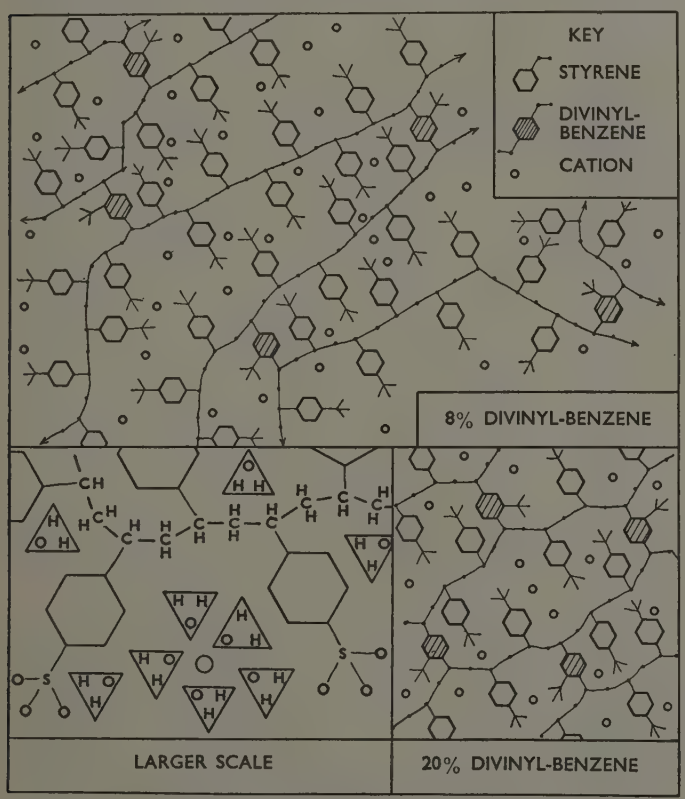

FIGURE 1 – *Schematic representation of cross-linked sulphonated styrene exchangers. Note the much more rigid cross-linking for a high divinyl-benzene content.*

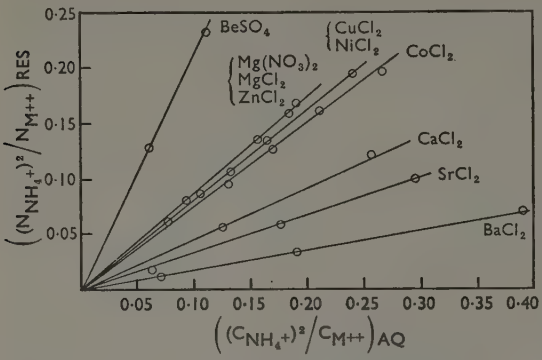

FIGURE 2 – *Test of equation 3 for the exchange of heterovalent ions. (After Kitchener and Kressman* [5].)

the inability of very large cations such as

$$N(C_2H_5)_2(CH_2C_6H_5)_2^+$$

to diffuse into some of the resins.

No simple rule applies to the ions of the transition elements. The univalent ions Tl^+ and Ag^+ are more strongly adsorbed than other ions of the same valency, but the affinity of Cu, Ni, and Co, for example, lies between Mg and Ca (see figure 2).

When ions of different valency exchange, it depends to a large extent on the total concentration whether the separation factor k_s is larger or smaller than unity, i.e. which of the ions is the more strongly adsorbed. Let us take a case where the ions I and II are of the valencies v_1 and v_2 ($v_1 > v_2$), the aqueous concentrations are c_1 and c_2, and in the resin phase the equivalent fractions are x_1 and $x_2 = 1 - x_1$. Then the stoichiometric reaction of the exchange is (neglecting the movement of water during exchange):

$$v_2[\mathrm{I}]_{sol} + v_1[\mathrm{II}]_{res} \rightleftharpoons v_2[\mathrm{I}]_{res} + v_1[\mathrm{II}]_{sol} \quad ..(2)$$

which results at equilibrium in a mass-law equation

$$\left[\frac{c_1}{x_1}\right]^{v_2} \cdot \left[\frac{x_2}{c_2}\right]^{v_1} = k_e \quad .....(3)$$

The equilibrium factor k_e should not be confused with the separation factor k_s.

$$k_s = \frac{X_2 c_1}{X_1 c_2} = \frac{v_1}{v_2}(k_e)^{1/v_2}\left(\frac{c_2}{x_2}\right)^{(v_1 - v_2)/v_2} \quad ....(4)$$

Thus, while the ion with the higher valency is more strongly adsorbed in dilute solution, it follows from equation 4 that, by greatly increasing the total aqueous concentration, the relative affinity of the ion of lower valency (II) is increased, and the preference as expressed by k_s is sometimes reversed altogether.

The equilibrium factor k_e would be expected to be nearly independent of the total aqueous concentration and of the ratio of the ions in the resin phase, and indeed, if $x_1^{v_2}/x_2^{v_1}$ and $c_1^{v_2}/c_2^{v_1}$ are plotted as abscissae and ordinates respectively, the curves obtained are often reasonably linear (see figure 2, from the paper by Kitchener and Kressman [5]).

That they do not always follow the linear plot accurately is due to a number of simplifying assumptions which are contained in equation 3. Strictly, one should have used, not concentrations and equivalent fractions of the ions, but the electrolyte activities in the solution and in the resin phase. For the aqueous phase, these can sometimes be evaluated from tables, but, up to now, we know almost nothing of the activities in the resin phase, and the estimation of their values depends largely on the assumptions made by different authors. Moreover, in equations 2 and 3 the movement of water in and out of the resin phase, due to the different hydration of different ions, has been neglected. To consider it would lead to another term in equation 3 containing the water activities, and the change also affects the activities of the ions in the resin phase. At high aqueous concentrations, yet another factor comes into play, as the resin takes up electrolytes in addition to the exchangeable ions, thereby greatly affecting the internal 'concentration' and the activity coefficients.

In high-capacity resins these deviations from the ideal can be very marked, especially when ions of the transition group elements are concerned. Figure 3 shows variations of k_e (which, if the

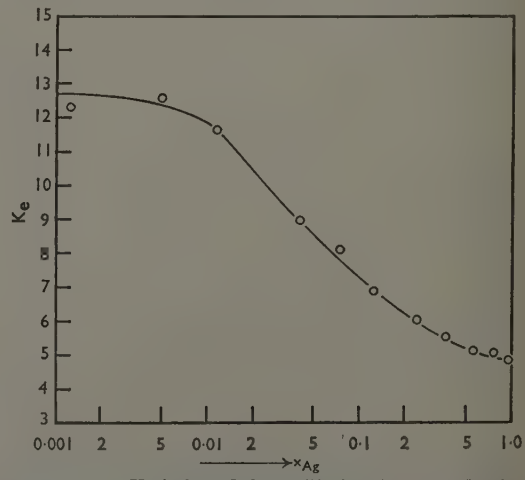

FIGURE 3 – *Variation of the equilibrium 'constant'* k_e *for the exchange of silver against sodium on Dowex* 50 *with the fraction of silver on the exchanger* [7]. $k_e = x_{Ag}a_{Na}/x_{Na}a_{Ag}$.

equivalent fractions did represent the activities, should be almost constant) with composition of the resin, for the exchange of Na and Ag on Dowex 50 (a commercial product). As the equilibria of figure 3 were determined in dilute solutions, and as, moreover, the activity coefficients in the aqueous phase were taken into account, the cause of this deviation from the ideal must be sought in the resin phase; the only phenomena which can explain this big variation of k_e must involve a fairly energetic interaction between the two adsorbed cations. This interaction may be due either to a dehydration of one ion by the other, or to mutual electrostatic repulsion of the ions, which in the circumstances may vary the degree of formation of ion-pairs with the sulphonate group of the resin. Increased ion-pair formation by one of the exchanging cations would lower the activity of this cation in the resin phase, and thereby result in its being more strongly adsorbed.

SWELLING AND ELECTROLYTE-UPTAKE OF RESINS

Experiments in this field are concerned with the following factors:

1. The loss of water by resins with different cations under reduced water-vapour pressure [2]. (See figure 4.)
2. The loss of water, and
3. the uptake of excess electrolyte by the resins when in contact with concentrated aqueous solutions containing salts of the exchanging cation [2].
4. The conductance and the electrolytic transference in the resin [2].

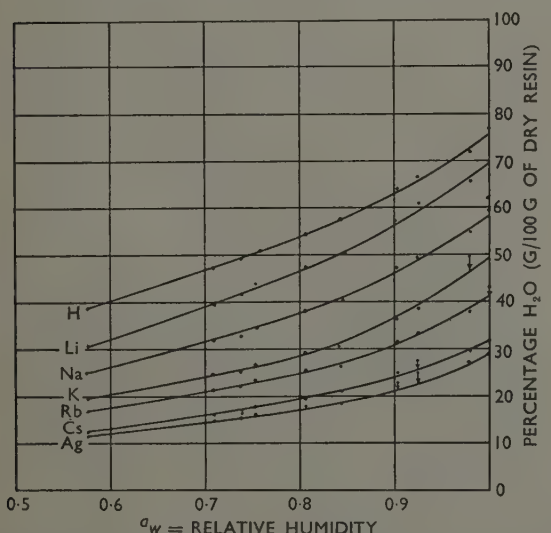

FIGURE 4 – *The swelling-water content of Dowex* 50 *with different cations under varying water-vapour pressure* [7]. $a_w = p_{H_2O}/p_{H_2O\ saturated}$.

Some results are shown in figure 5. They show clearly the considerable volume change which the resin undergoes when placed in solutions of various concentrations. It is apparent that a physico-chemical treatment of resin equilibria must take into account the work involved in elongating or contracting the cross-linked chains of the resin. These experimental results make it necessary to visualize the resin phase as a concentrated aqueous electrolyte solution constrained by the somewhat elastic resin structure, which prevents the resin from swelling beyond a certain limit. The application of thermodynamics [2] to such a model makes it possible to estimate roughly the amount of electrolyte-uptake observed in experiments of the type shown in figure 5. In doing so, it is found that the actual uptake considerably exceeds the theoretically estimated one, which can only mean that the electrolyte activity inside the resin is considerably smaller than it would be if the mean molal activity coefficients of the resinate had values comparable to those of other Na salts, e.g. chlorides or nitrates. The same conclusion has been reached by W. Juda from the determination of transport numbers inside the resin phase [2]. This means that an Na resinate, considered as an aqueous solution of Na ions and sulphonate ions, does not dissociate completely into two ions which can be treated as entirely independent particles in the solution. This may be so for several reasons:

1. Dissociation into anion and cation may be incomplete, possibly as a result of the presence of organic matter which would reduce the dielectric constant.
2. The anionic groups, being attached to the resin structure, may not act as completely independent particles.
3. The ionic atmospheres—as envisaged in the Debye-Hückel theory of electrolyte solutions [6]—are different from those in an aqueous solution. This may be due either to the space restrictions imposed by the organic resin matrix, or to the restricted mobility of the anions (in a cation exchanger), which does not make possible the formation of a negative ionic atmosphere around a cation.

All these possibilities act in the direction of a reduction of the mean activity and osmotic coefficients of the metal resinate, and as all of them may occur simultaneously (but to a different

degree for different ions) it will not be easy to express these considerations quantitatively.

There are, however, a number of features which show that the concept of treating ion exchangers as concentrated aqueous electrolytes goes a long way towards an understanding of their fundamental properties [2].

Taking the case of the sulphonated cross-linked polystyrenes (of which Amberlite I.R.120, Dowex 50, and Zeo-Karb 225 are well-known commercial types), variations in the cross-linking of the monomer polystyrene chains can be effected by varying the amount of divinylbenzene (see figure 1). The smaller the amount of cross-linking, the less are the forces which oppose the tendency of the resin (a tendency common to all electrolytes) to form a real aqueous solution when in contact with water. This means that a resin of low cross-linkage in contact with dilute aqueous solutions will swell much more than a highly cross-linked one. Also, considered as an aqueous electrolyte solution, the swollen resin of low cross-linkage, though its capacity per gram of dry resin is very nearly the same, has a smaller resinate molality (= number of equivalents of exchanging groups per 1000 gm of swelling water).

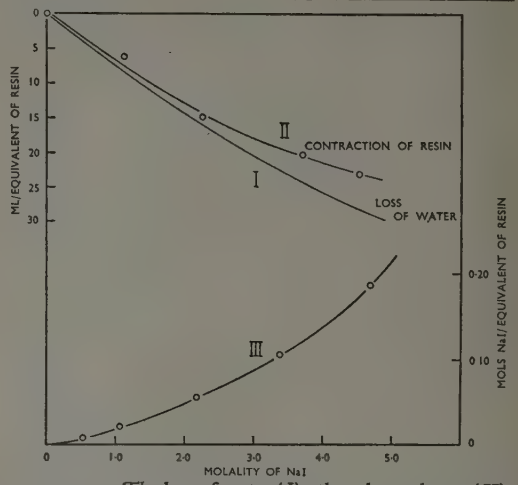

FIGURE 5 – *The loss of water (I), the volume change (II), and the uptake of NaI (III) by Na-Dowex-50, when in contact with aqueous sodium iodide solutions of different concentrations* [7].

SPECIFICITY OF RESINS OF DIFFERENT CROSS-LINKAGE [2]

When two electrolytes are present, and we have the comparatively simple case of both cations being univalent and the aqueous solution dilute, the theory for a somewhat idealized case leads to a value for the equilibrium factor k_e'

$$\ln k_e' = \ln \frac{\overline{m}_2}{m_2} \cdot \frac{m_1}{\overline{m}_1} = \frac{P}{RT}(V_1 - V_2) + \ln \gamma_{R_1}/\gamma_{R_2} \quad (5)$$

where γ_{R_1} and γ_{R_2} are the mean molal activity coefficients of the two pure resinates, P is a function of the resin volume equivalent to the 'swelling pressure' of the resin, V_1 and V_2 are the ionic volumes of the unhydrated cations, and the m's and $\overline{m}$'s are the molalities in the aqueous and resin phases respectively, which in the latter case are computed as if the resinate were dissolved in the swelling water. Now, the activity coefficients of unhydrated electrolytes in general are smaller, the bigger the ionic volumes of the unhydrated cations, e.g. $V_{Cs} > V_{Na}$ and $\gamma_{CsCl} < \gamma_{NaCl}$. The two terms on the right-hand side of equation 3 have therefore different signs. As it is known from experiment that k'_e increases with increasing value of $V_2 - V_1$, it is apparent that the term $\ln \gamma_{R_1}/\gamma_{R_2}$ is predominant, and the swelling-pressure term cannot be very significant from the point of view of the separation factor. Using the same model for ions of different valency (v_1 and v_2), the equilibrium factor becomes

$$k_e' = \left(\frac{\overline{m}_2}{m_2}\right)^{v_1} \cdot \left(\frac{m_1}{\overline{m}_1}\right)^{v_2} \quad \ldots\ldots\ldots (6)$$

where k_e' is a complicated function of the swelling pressure, the ion volumes, and the activity coefficients. As the trend of the series from Ba to Be shows, the predominant factor is the last. However, the molalities in the resin phase are not a convenient means of presenting the phase composition, as they require a knowledge of the water content of the resin. Their ratio can conveniently be replaced by that of the equivalent fractions, $x_1 = v_1 n_1/(v_1 n_1 + v_2 n_2)$ and $x_2 = v_2 n_2/(v_1 n_1 + v_2 n_2)$, as $(v_1 n_1 + v_2 n_2)$ is the resin capacity and thus constant. It cannot be replaced by the molar fractions $X_1 = n_1/(n_1 + n_2)$ and $X_2 = n_2/(n_1 + n_2)$ as the total number of mols/gm of resin $(n_1 + n_2)$ in a heterovalent mixture is itself a function of the ratio of the two ions in the resin. This supplies the explanation for the experiment of Duncan and Lister [4], who showed that, in the case of an NH_4—La exchange, a better constancy of k_e' is obtained using equivalent fractions than with molar fractions.

Returning to equation 5, we noted that the equilibrium factor k_e' is mainly a function of the ratio of the activity coefficients of the two resinates. It is a well-known fact that activity coefficients of

aqueous electrolytes are very similar in dilute solutions where they follow the Debye-Hückel limiting law, but that they diverge as the concentration increases. It is apparent, therefore, that as we decrease the cross-linking and thus, owing to increased swelling, turn the resinate into a more dilute 'solution,' the ratio of the activity coefficients and thus also the value of k_c' should decrease, i.e. the resin should become less effective for the separation of ions. Experiment [2] shows that this is indeed the case.

The natural consequence of this realization might be to conclude that the highest possible cross-linkage should prove most favourable for obtaining resins of high specificity. In practice, however, there is a limit to the useful increase of cross-linkage, as greatly increased cross-linking produces resins which show a very abnormal behaviour. To give an example: resins cross-linked with 20 or more per cent. of divinylbenzene, while showing a great preference, e.g. for Na^+ in an Na-H resin containing mainly H^+, show a preference for H^+ in a mixture containing mainly Na^+, with an intermediate resin composition where little or no enrichment of either ion takes place. A reason (not necessarily the only one) for this behaviour can be found if we consider that highly cross-linked resins contain very little water, and that consequently the cations in the resin do not find enough water to satisfy their normal hydration requirements. They will therefore proceed to share the available water molecules in a manner which provides the lowest possible energy level. This means that interaction will take place between different ions of the same sign—a possibility which, according to Brønsted, need not normally be considered in more dilute solutions [6]. Such an interaction would lower the mean activity in the resin of the less numerous cations more than those of the more plentiful variety, with the result that the cation species present in the minority would show a tendency to be more strongly adsorbed.

There are other considerations which make it undesirable to increase the cross-linkage of the resins beyond a certain extent. As the resins swell less, their porosity, which provides for the free and fast interchange with the ions of the solution, decreases, and the exchange velocity, which is—except in extremely dilute solutions—controlled by the diffusion of ions inside the resin phase, decreases very rapidly. Indeed, for very highly cross-linked resins, access into the interior of the resin is no longer possible for large organic ions [2].

A feature of physico-chemical interest which has so far not been specifically mentioned is the different degree of swelling of a given resin when the exchangeable cation is varied. As we change, for example, from Li to Na to Rb to Cs we find that the resin contracts owing to loss of water (see figure 4). We may explain this in various ways. We can say that each of these ions is more hydrated than the subsequently-named ones, or we may say, treating the resin as an aqueous electrolyte solution, that the osmotic coefficient of the resinates decreases in the given order, thus causing less swelling. Actually, as the osmotic coefficients of electrolytes in concentrated aqueous solutions are effectively determined by the degree of hydration of their cations, both explanations must indicate the same trend. However, the latter one gives not only a possibility for quantitative treatment, but leads also to the conclusion that cations of the same valency should be the more strongly adsorbed the less they swell the resin, and *vice versa*. Except for hydrogen, this conclusion is in agreement with the general body of experimental data.

CONCLUSIONS

It is clear that it is not possible to do more here than to touch on the various conceptions connected with the mechanism of ion exchangers, a field in which we are only just beginning to see light. Our difficulties in obtaining a complete understanding of what is going on inside the resins are increased by the fact that we are obviously dealing with what might be described as highly concentrated solutions of strong electrolytes, a subject yet little explored [6]. However, the extensive research in progress on both sides of the Atlantic shows that interest in this field is stimulated rather than discouraged by these difficulties.

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'Mr Warltire, a good chymist'

DOUGLAS McKIE

Although John Warltire gave valuable assistance to Joseph Priestley in the isolation of oxygen in 1774, and although he observed, late in 1776 or early in 1777, that a 'whitish cloud' was produced in the combustion of 'inflammable air,' practically nothing has been known of him and no biographical notice or study of his writings has hitherto appeared. Dr McKie's article is therefore a welcome addition to the biographical literature of chemistry.

John Warltire is known to historians of chemistry as an itinerant lecturer and a friend of Joseph Priestley. When, in 1774, the latter was planning the series of experiments with his new burning-glass which led to the isolation of dephlogisticated air or oxygen, he recorded that 'Mr Warltire, a good chymist, and lecturer in natural philosophy, happening to be at that time in Calne, I explained my views to him, and was furnished by him with many substances, which I could not otherwise have procured' (*Experiments and Observations*, London, 1775, ii, 34). In the course of these classic experiments, Priestley was doubtful of the genuineness of the *mercurius calcinatus* that he was using, having bought it 'at a common apothecary's', and obtained from Warltire a sample that he 'could warrant to be genuine' (*ibid.*, p. 36).

On 3rd January, 1777, Warltire wrote to Priestley to inform him of a number of observations that he had made. Among them, he reported that in the burning of a jet of inflammable air (hydrogen) in a receiver filled with common air, 'the common air is contracted full a fifth part of its original dimensions; immediately after the flame is extinguished, there appears through almost the whole of the receiver, a fine powdery substance like a whitish cloud' (*ibid.*, 1777, iii, 367).

This remarkable observation, made by Warltire late in 1776 or early in 1777, does not seem to have been noticed before by writers involved in the 'water controversy,' but it led Warltire to further and better-known experiments, which he discussed with Priestley and which were communicated to Cavendish, as Cavendish himself acknowledged. Warltire next fired mixtures of common air and inflammable air in a closed copper globe, using weighed quantities, with the object of determining the currently debated problem of whether or not heat had weight, and on clearing the globe with a draught of air from a bellows for the next experiment, he 'observed a smoke escape along with it.' Priestley, that intrepid experimenter, had, however, told Warltire that he thought it safe to use glass vessels, and squared his practice with his preaching by making such experiments in Warltire's presence. Warltire followed suit and 'observed, as you [Priestley] did, that though the glass was clean and dry before, yet, after firing the air, it became dewy. . . .' (*Experiments and Observations*, Birmingham, 1781, ii, pp. *396–7). The letter describing these results is dated 18th April, 1781.

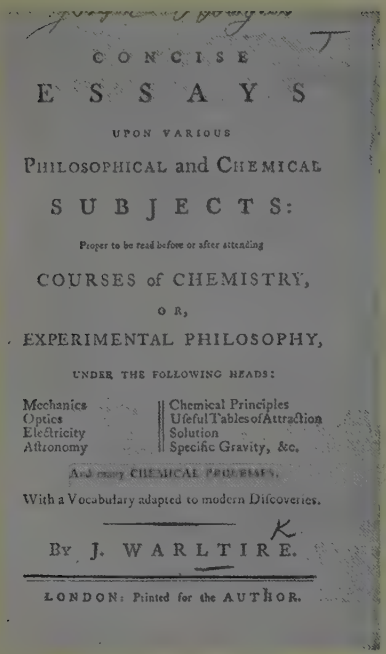
Priestley, in commenting (1781) on this observation, wrote: 'I must add, that the moment he [Warltire] saw the *moisture* on the inside of the closed glass vessel . . . he said that it confirmed an opinion he had long entertained, viz. that common air deposits its moisture when it is phlogisticated' (*ibid.*, p. *398). Priestley shared this view.

The dew was afterwards identified by Cavendish as plain water. His explanation of its production differs little, if at all, from that of Warltire and Priestley, since he supposed that it was deposited from both gases, the common air and the inflammable air, into the composition of both of which it entered as water.

An acute observer, a good experimenter, a successful lecturer, the friend and associate of Priestley, Cavendish, Erasmus Darwin, Wedgwood, and others, Warltire played no mean part in eighteenth-century chemistry. Search over many years, involving many fruitless inquiries, has brought to light a few details of his life.

According to family tradition, Warltire was of Greek descent, and came to England in early life as a refugee from religious persecution. His publications, and other sources, show that he was an itinerant lecturer in natural philosophy.

On 22nd November, 1762, John Warltire, then aged twenty-three, a bachelor, living in the parish of Wolverhampton 'for the space of four weeks last past', was party to a marriage bond and took the oath relating to his marriage by licence on



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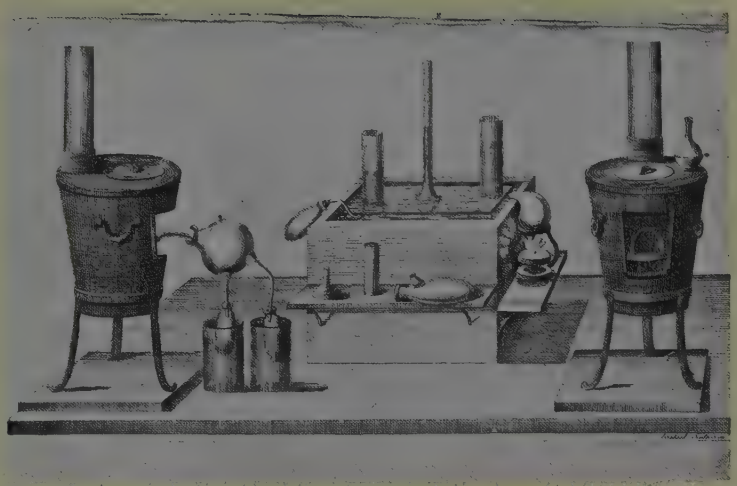

FIGURE 1 – *Title-page of the* Concise Essays (*London*, c. 1775), *with an accompanying illustration of apparatus.*

ANALYSIS

Of a COURSE of

LECTURES

IN

Experimental Philoſophy;

With a brief Account of the

Moſt neceſſary Inſtruments uſed in the Courſe,

AND THE

Gradual Improvements of SCIENCE:

Intended chiefly for the Uſe of the Author's Audience.

By *JOHN WARLTIRE,*

Lecturer in PHILOSOPHY.

The FIFTH EDITION.

EXETER:

Printed, for the Author, by R. TREWMAN,

behind the Guildhall. 1802.

FIGURE 2 – *Title-page of the* Analysis (*Exeter*, 1767), *with accompanying illustrations of apparatus.*

that date in the parish church of St Peter, Wolverhampton, to Mary Stringer, minor, and a spinster of the same parish, daughter of William Stringer. The marriage bond and affidavit are preserved in the Diocesan Registry, Lichfield. This gives Warltire's year of birth as 1739, or possibly 1738. One of the still unsolved difficulties in tracing details of Warltire's life is that no place of residence has so far been found on any relevant document. The old parish of Wolverhampton was much larger than the present parish of that name. Some letters by Warltire seem to have been written from Birmingham, and there is a tradition that he was a partner with Keir in a glass-works at Stourbridge or Wordsley.

Warltire early took to lecturing and writing on science. Already in 1766, when he was twenty-seven, a fourth edition (the only copy of any edition so far traced) of his *A Short Account of the Solar System; Air and Atmosphere; Electricity; and of such Instruments as are necessary to make Experiments, particularly to explain and demonstrate those Sciences. Intended chiefly for the Use of such Ladies and Gentlemen, who attend the Author's Lectures upon those Subjects*, was published in London. This 'fourth edition' may not indicate a great circulation; it seems probable from a consideration of his other works that Warltire had books printed in connection with his lectures, and that when he lectured a new title-page was used after being set up by a local printer. All Warltire's books are now rare.

Another work by Warltire was *Concise Essays upon Various Philosophical and Chemical Subjects: Proper to be read before or after attending Courses of Chemistry, or, Experimental Philosophy*, etc. (London, no date). The British Museum Catalogue suggests 1770 for the date of publication, but as dephlogisticated air, which was not isolated until 1774, and was not so named by Priestley until 1775, appears in the text, the book cannot be earlier than 1775. A later edition of the *Concise Essays*, etc., was published in Nottingham in 1781. Other books include *Analysis of a Course of Lectures in Experimental Philosophy; with a brief Account of the most necessary Instruments used in the Course, and the Gradual Improvements of Science: Intended chiefly for the Use of the Author's Audience*, etc. (Exeter, 5th edn., 1767; London, 6th edn., 1769); *Tables of the Various Combinations and Specific Attraction of the Substances employed in Chemistry. Being a Compendium of that Science: Intended chiefly for the Use of those Gentlemen and Ladies who attend the Author's Lectures*, etc. (London, 1769); *A Course of thirteen Lectures upon General Chemistry; including the Theory and Experiments agreeable to the latest Discoveries* (a syllabus of the course, without place or date of publication); and *Synopsis of Natural and Artificial Chemistry* (without place or date of publication, mentioned by H. C. Bolton in his *Bibliography of Chemistry*, and the only work named here not seen by the writer). All these books seem to have been printed in the places where Warltire lectured: some bear the words 'Printed for the Author.' The *Course of thirteen Lectures* states that 'Subscribers pay One Guinea for the Course and may send Substitutes. Non-subscribers pay 2s. 6d. for every Lecture they attend.'

Warltire was well known to Priestley in 1774, as we have seen. In 1774 or 1776 Erasmus Darwin invited his help in experiments on the cooling produced in the receiver of an air-pump on evacuation; the experiments were reported much later in the *Phil. Trans.* (1788, **78**, 43), where Darwin described Warltire as 'a celebrated itinerant teacher of natural philosophy.'

Warltire gained recognition among his scientific contemporaries. On 2nd October, 1782, he was elected an honorary member of the Manchester Literary and Philosophical Society; his name appears in the list in the first volume of the Society's *Memoirs* (1789). Honorary members were such as had distinguished themselves in the various fields in which the Society was interested, and were resident at some distance from Manchester and so unable to attend the meetings. Warltire was one of the forty-five honorary members; his colleagues included John Aikin, John Coakley Lettsom, Magellan, Priestley, Benjamin Rush, Samuel Foart Simmons, Volta, Wedgwood, Martin Wall, Vic d'Azyr, Erasmus Darwin, Benjamin Franklin, Richard Watson, and Lavoisier. Warltire's name appears in the lists up to 1790, but not later.

A few other details of Warltire's life have been gained from certain letters preserved in the Assay Office, Birmingham, and the Wedgwood Museum, Barlaston. We quote from these by the courtesy of the Assay Master, Birmingham, and Messrs Josiah Wedgwood and Sons.

On 28th September, 1776, Priestley wrote from Calne to Matthew Boulton: 'I take the liberty to recommend to you Mr Warltire, who [has] been sometime in this part of the [cou]ntry, and who is going to read Lectures on the subject of *air* at Birmingham. I think him an excellent philosopher, as well as a modest and agreeable man. He is perfectly acquainted with his subject, and has prepared a set of experiments which have given the greatest satisfaction wherever he has

been. He has been so obliging as to spend some time with me, and has given me much assistance . . .' (MS., Assay Office, Birmingham).

We quote next from the draft of a letter to Warltire of 5th February, 1779, in Wedgwood's own hand: 'I was very unlucky & much mortified in being from home when you did me the favor of a visit at Etruria but hope for better fortune another time. Your favor of the 27th ultimo was duly rec^{d} & would have been replied to sooner but I wish'd to be thoroughly satisfied of your having a tolerable subscript^{n} here before I ventur'd to give you any encouragement to come amongst us, & though I am now fully convinced of there being sufficient subscribers to make up your number & I apprehend many more yet some gentlemen . . . think you would have more company about midsummer, perhaps two courses instead of one, as several will now be in town & others taken up with field diversions. Having thus stated the case to you as it appears to me it must remain with you to determine whether you will visit us about the 20th inst. or defer giving us that pleasure 'till midsummer. In either case I have not the least doubt of your meeting a handsome subscription but believe you would be better attended at midsummer.' (MS. E. 18875-26, Wedgwood Museum.)

Evidently Warltire elected for the earlier date; for Wedgwood wrote to Thomas Bentley on 17th February, 1779, to say that 'Mr Warltire comes here on Saturday next to give us some instruction, & as my neighbours seem determin'd to receive it only three days in the week it will make it long before I shall have the pleasure of seeing you at Turnham Green.' (MS. E. 18877–26, Wedgwood Museum.) On the 25th of the same month, Wedgwood wrote again to Bentley: 'Mr Warltire open'd his lecture on Tuesday with a subscription of about 30 Guineas, and I think he will have more. Doct^{r} Darwin has sent his son Rob^{t} to attend the course, & my Jack & this young Doct^{r} is to be have both taken the infection very kindly. They both attend Mr Warltire every morning for private instruction which is of much greater consequence to them than the public lectures.' (MS. E. 18878-26, Wedgwood Museum.)

A later letter of 8th March, 1779, from Wedgwood to Bentley, stated that Warltire had used one of Martin's 'solar microscopes' in his lectures, and that this had led to the exhibition of cameos by its means, and to proposals for its wider use in exhibiting other works of art, the solution and precipitation of metals, crystallization, animalculae, and the circulation of the blood. (MS. E. 18882-26, Wedgwood Museum.)

In September 1781, Warltire gave a course of lectures at Chesterfield. Matthew Boulton, writing to Watt on the 25th, said: 'We stopped again at Chesterfield . . . I found Mr Warltire there teaching Chymical Philosophy to the Chesterfieldians.' (Boulton MSS., Birmingham Reference Library.)

On 19th June, 1784, Christopher Gullett wrote from Beerferris to Matthew Boulton at Truro, referring to some assays by 'your worthy Friend Mr. Warltire,' and quoting an extract from a letter by Warltire from Topsham, written on 24th May, 1784, to the Rev. W. Radcliffe of Plymouth, giving assays of lead ores containing a large proportion of silver. (MS., Assay Office, Birmingham.)

The last detail of Warltire's active life that we have been able to trace refers to a 'Course of ten lectures on the most interesting parts of Natural Philosophy' given at Rotherham in 1803, when he had been 'a lecturer for about 50 years on these subjects.' (H. McLachlan, *English Education under the Test Acts*, Manchester, 1931, p. 203.)

One announcement of a course of lectures by Warltire has been traced. It appeared in the *Exeter Flying Post* for 10th April, 1767, and stated: 'A Course of Experimental Philosophy; at Mr Castiglione's in Gandy's Lane, Exon; to begin on Monday the 13th of April at four in the afternoon. By John Wa[r]ltire.'

Warltire died in Tamworth and was buried on 23rd August, 1810. He was described as 'a tall dark-complexioned man, with long black hair, and a pale face.' It was said that in his early life he had lived among the Arabs, but the most alarming experience that befell him occurred in the lonely moorland district of Morridge, when he was travelling on horseback from Bakewell to Leek. His account of this blood-curdling adventure formed the basis of a local story by Roger Rochcliffe, which appeared in the *Leek Times*. It rivals the adventure of Denys and Gerard among the murderous robbers in the inn in *The Cloister and the Hearth*. (*Olde Leeke*, ed. M. H. Miller, reprinted from and published by the *Leek Times*, 1900, second series, pp. 217–20.)

The writer is greatly indebted to the many correspondents and librarians who have helped him to trace these details, especially to Mrs G. Warltire; Councillor W. Tildesley; Mr Westwood, Assay Master, Birmingham; Mr A. E. Dodd, M.Sc.; and to the never-failing and generous assistance of the former City Librarian of Birmingham, Mr H. M. Cashmore, F.L.A.

The birth and growth of a volcano

FREDERICK H. POUGH

The study of volcanoes, both extinct and active, has proved a fruitful source of information both about the deeper layers of the earth and about the forces which have shaped its crust. It is, however, unique for a volcano to have been kept under close observation almost from the day of its birth, and for this reason the story of Parícutin is of exceptional interest.

In February 1943 the world's preoccupation with more important events reduced the impression made upon the public, and upon geologists, by the appearance of a new volcano in a Mexican cornfield. Eight years have passed, and continuous eruptions from the original small crater have now piled up a sizeable cinder cone, while many square miles of former fields and forests are buried deep under many feet of lava. The new volcano was named Parícutin, after the nearest Indian village, and lies near the centre of the State of Michoacan, about 200 miles south-west of Mexico City.

This spot is but a few miles from the western edge of the high Mexican plateau, and the elevation of the base is about 8200 feet. The cone rises approximately 1600 feet above the base, though its total height appears somewhat less because of the submergence of several hundred feet of the original structure in the flood of lava which laps its flank. In its early stages the cone grew rapidly, but increasing size and steadily diminishing explosive activity have slowed its growth, so that the final elevation will probably not be much greater than that which it now has.

The belt in which it lies is a band of volcanic products overlying a basement of sediments and granitic rocks. The great volcanoes of Mexico punctuate the belt, the greatest of all, Orizaba, marking the eastern edge. Popocatapetl and Ixtaccihuatl vie with each other for tourist attention near Mexico City, and Colima perches on the Pacific border. Smaller volcanic structures dot the intervening countryside; the smallest and most numerous are the thousands of cinder cones which lie on every hand. Parícutin is just another cinder cone. Geologically speaking, it was to be expected, just as its predecessor Jorullo, born in 1759, was to be expected, and as Parícutin's successor of an unknown number of years hence is equally certain to appear. Though many peaks are deeply weathered (Ixtaccihuatl no longer shows a crater) seismically and volcanically, the Mexican volcanic belt is still very much alive. Within its geological limits are textbook examples of several types of volcanic structure.

At the time of Parícutin's birth it was, of course, impossible to make any accurate estimate of the probable duration of its activity. It grew very rapidly at first, and within a few weeks had attained a height of several hundred feet. By May 1943 it was 1000 feet high, forming a beautifully symmetrical cone about 1000 feet across at its summit and over half a mile through at the base. The frequent and violent explosions from the crater made a magnificent spectacle. After the first few weeks, the original character of the activity—largely an ejection of bombs (lumps of molten rock) and lava shreds unaccompanied by fine material—changed, and the eruptions for the next few years, with irregular but recurrent reversions to the earlier type, were characterized by tremendous quantities of solid material, ranging from a light grey powder to coarse lapilli. All the immediate countryside was smothered by this ash, and within half a mile of the cone the deposits attained a depth of 20 feet. Since the prevailing winds of the dry season blow from the north-east, the deposits were not uniformly distributed around the cone, but piled higher and spread further south and west of the vent. A reversal of the winds during the rainy season with normal, minor, fluctuations produced heavy ash deposits all around the cone, slowly thinning out to a thickness of a few inches at ten miles or more from the source.

The forests immediately surrounding the volcano are mainly pine and oak. They were adversely affected by the ash, and the pines soon turned yellow; those near the cone died within a year. Oaks proved to be somewhat more resistant and kept sprouting new growths repeatedly, but in time they too succumbed. Several factors were involved, of which the most important was probably an abrasive and clogging effect of the ash-coating on the leaves. A secondary and

slower agent was the deeper burial of the roots, which reduced the vitality of the already severely affected trees. Pine branches near the cone were stripped of bark, and their upper surfaces were worn as if sandpapered.

In addition to the upper surface abrasion of the falling ash there was an additional complication from the blowing dust. During the dry season, from November to June, the sun shines daily on bare fields covered with a thick layer of light, loose, and very fine rock-dust. Local heating makes strong convection currents which race across the field, picking up the powder and blowing it here and there across the country. On such days, life near the volcano becomes very trying. The clouds of dust in the air often obscure all objects more than a score of feet from the observer.

Supplementing the ash, and contributing largely to the mass of the cone, is the much coarser material ejected from the mouth of the crater. The bombs which form the framework of the cone are sometimes numerous, and may, rarely, measure two yards across. Most of them seem to have been solid when they were ejected; indeed, some may have been shot from the vent repeatedly and fallen back into the crater several times before achieving a trajectory which let them descend on the sides of the cone or beyond its base. As a result, their shaping often appears to be largely mechanical; it may even be that in their milling about at the bottom of the crater's funnel they have ground off some of the fine dust that towers so high above the cone. The viscous character of the lava, together with its fairly low temperature, has prevented a marked development of the characteristic oval bombs that are the classic types of volcanic ejecta. Even though they have whirled over and over in the air and then charged like racing fireballs down the side of the cone, their exterior is little shaped by the rotation. Many of them shatter on impact; they seem to be under strain, for they fracture easily, and very few show any sort of crust.

Sometimes, after a brilliant evening burst of hot and fluid lava, one does find bombs showing something of the shaping that is usually expected. Some of these rare bombs have even more liquid interiors, and crack as they strike, to emit a little comb of glassy needles along the line of the fissure. Such bombs were always rare, and were produced only at times of intense crater activity, when great bursts of red, liquid rock were seen rising up and spreading out as they fell in showers that silhouetted the cone in fire. Another type of bomb was elongated and striated, suggesting that the material had been squeezed out of an irregular opening before ejection, much as toothpaste assumes the cross-section of the aperture from which it escapes. As with most of Parícutin's lava, the high viscosity permanently preserved the shapes on cooling.

Occasional bombs were composed of granitic rock, which was encased in a shell of basalt. These presumably represent some of the underlying crust through which the lava had risen. The earliest bombs of this type were almost white, quite fresh, and comparatively unaltered in their outward appearance. In thin section, some bits of intergranular glass and a start of remelting could be noted. In time, the granitic bits became more and more altered, eventually giving place to a frothy white pumice, but remaining discrete as distinct acidic drops in a basalt magma. One of the last fragments of the pipe-wall that was found had been so thoroughly remelted that it was transformed into a grey, streaked obsidian, which fell on the cone in a rind of plastic basalt. Before cooling, the basalt peeled back, splitting a clinging wedge of brittle grey glass into a row of separated teeth along a basalt jaw. Bombs of granitic material are no longer produced by Parícutin; they were common only in the earliest days, and never amounted to more than a very small proportion of the total ejecta.

Great quantities of lava have escaped continuously in a long succession of flows from numerous vents flanking the cone. A single orifice was situated half-way up the side of the cone; all the others have been lower down, nearer to, or well outside, the base. They have been explained as originating on two parallel fault lines running from the north-west to the south-east, and the variously named mouths have lain along these lines. In particular, the original lava flows came from the main vent or from very near it, and were able to transport on their surface some of the material of the cone itself. Such loose masses were carried as much as half a mile away from the spot where they grew, to form three-hundred-foot mounds; these would be very hard for another generation of geologists to explain except as secondary cones with collapsed craters, had their formation not been observed. Some of the suspect descriptions of parasitic mounds around Jorullo can possibly be better interpreted in the light of these observations. Despite repeated destruction of the sides of the cone by escaping lava flows, the cone up to now has been able to repair itself.

After several years it is still almost symmetrical, although higher at the moment on its north-west side, but still growing and still maintaining a classic outline.

In latter years, the lava vents have been further from the cone, and hence have not affected the symmetry so greatly. Their lives as lava springs appear to be long. A western group of vents was continuously active for four years; the present vents on the south-east started early in 1948, and are still producing lava to feed the flows.

There have been no major changes in the lava or its behaviour since the start. The earliest lava immediately assumed the appearance of a great wall of tumbling blocks, the centre fluid, but very viscous, and the periphery enough cooled to be brittle. After about a year, it was noted that the average flow-temperature seemed to be slightly higher—sufficiently higher for the freshly exposed lava to drip off in a sticky mass after a face had crumbled away. Since the vents of most of the early flows were concealed beneath cone debris, the more liquid character of the lava at its point of escape could be observed only occasionally. The first liquid flow was of brief duration and occurred in June 1943. After a few hundred yards of rapid advance, this material stiffened and became blocky. In February 1944, the new series of vents that opened on the north-west side of the cone showed fine fountains at the vents, bubbling with sludgy, but liquid, lava for a period of several weeks. This lava flowed like heaving mud, forming large black curds on the surface which finally jammed and came to rest after travelling fifty feet or so. The still liquid lava beneath flowed on, carrying a welter of shattered black rocks on its surface, and gradually spread outwards into a great lava pool with a broadly advancing front. The front, however, was of the typical solid blocky type. Truly liquid red lava became visible at a distance from the vents only when a tongue was advancing rapidly down a gulley, as in the case of the flow which finally invaded the town of San Juan de Parangaricutiro, three miles away in a direct line but much more by the downhill route sought out by the lava stream.

The long San Juan stream, which has travelled farthest of all from its source, is marked, now that it has solidified, by more ashy lava than that of the other flows. Its surface shows an anastomosing pattern, as if the invading tongues had squeezed out of many crevices instead of coming down as the usual blocks. The greater quantity of gas indicated by the open texture of the cooled lava may explain this difference in its behaviour, and its greater extension. The quantity of gas accompanying the lava has notably diminished with time. At the end of the advance, the earliest flow-fronts were still fuming moraines long after all the movement had ceased. Each gas vent was lined with snowy crystals of ammonium chloride, with an occasional seasoning of mustard-coloured iron ammonium chlorides. Magnificent specimens of these water-soluble minerals could be collected around the crevices during the dry season; in fact, specimens could be produced to order by digging out such a vent and inserting suitably sized rocks for a few days of sublimation. The recent lava flows have been marked by no such line of guiding beacons, and ammonium chloride is now practically unobtainable in mineral specimens.

Hotter gases which form no collectable sublimates escape from the surface of the active flows. The advance of a lava stream at Parícutin, unlike those from volcanoes where the lava is more liquid, is not exactly like that of water. The initial flood of lava may spread over a large area, where most of it becomes stagnant and frozen. In time, the current becomes canalized, and while the main flow is dead, a narrow line of current stays alive. Its route can easily be charted by the line of blue fumes which hover along its path. Sometimes surfaces crusted solidly, and in March 1944 it was possible to walk almost at will over a flow that was still alive and flowing beneath our feet. The gas caught with this lava was responsible for two interesting phenomena, the development of small gas vents, known as hornitos, and the faint blue flames which flickered nightly above such orifices.

Hornitos or 'little ovens' sprang up on the surface of the crust over such a flow wherever a leak developed—a crack from which gas could escape with vigour, forcefully enough to blow out small fragments of black, melted, metallic-looking, highly reduced lava. In time, these shining building-stones piled up around the vent to form a glass chimney which might rise several feet in the air. The lining of these pipes was incandescent. Gusts of rising gas made the liquid inner surface flow upwards, welding the pile of fragments into a solid tube. At night, blue flames could be seen swaying above these vents, presumably caused by burning hydrogen set free by the reducing action of the filtering rock on the highly heated water vapour passing up through them. From time to

FIGURE 1 – *Incandescent bombs leave fiery trails on the film, outlining the cone against the evening sky. Only at dusk and after dark can the glow of the bombs be seen; by day they look black.*

FIGURE 2 – *Recent activity has robbed the crater of much of its explosive force. Lava is escaping on the flank and showing incandescence only near the vent and at the crumbling front.*

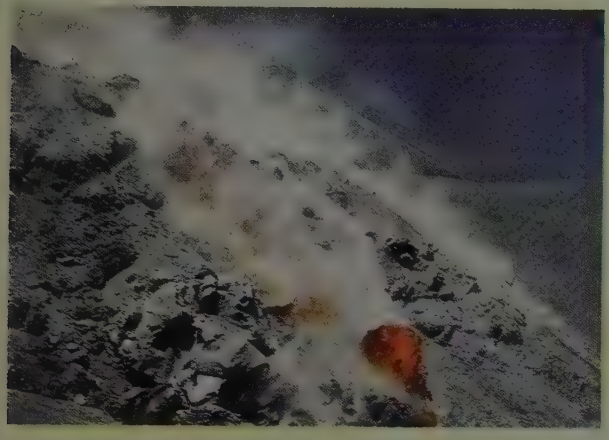

FIGURE 3 – *The viscous lava cools to brittleness and advances as a crumbling twenty-foot wall of hot loose stones, each freshly broken surface glowing redly for a few brief moments as the blocks tumble downwards.*

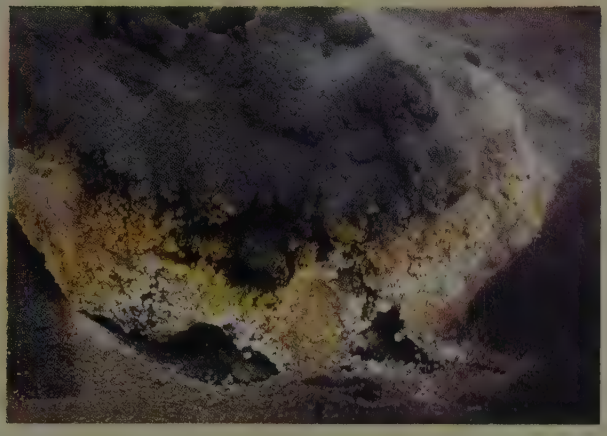

FIGURE 4 – *Trapped gases escape from frozen flows months after all movement has ceased. Around each hot fumarole colourful water-soluble salts form, ammonium and iron chlorides crystallizing directly from the gas at temperatures between* 200 *and* 500° *F.*

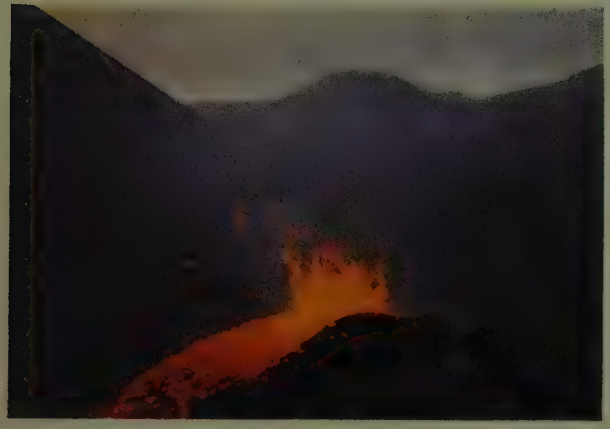

FIGURE 5 – *Accumulated gas caused lava fountain eruptions from a series of now dead vents near the base of the cone. The short-lived fountain and flow yielded the most fluid lava Paricutin has produced.*

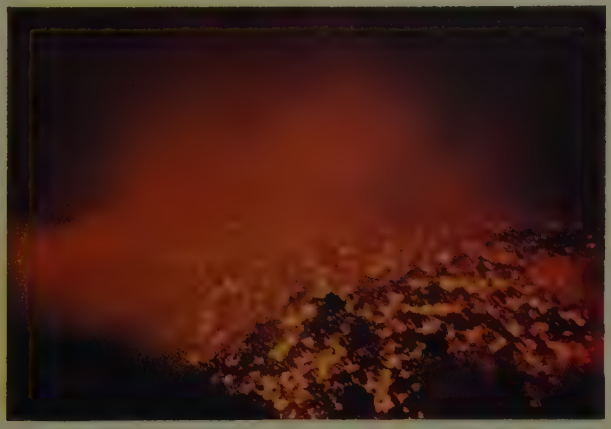

FIGURE 6 – *First stage in the birth of one flow was an upraised bed of glowing coals, flanked by unstable ridges of loose rocks and ash. On their collapse, fluid lava ran rapidly down the slope, covering several hundred yards in a matter of minutes. Movement in the ridge as this picture was taken gave warning that it was not a safe place for a prolonged stay.*

FIGURE 7 – *Exaggerated erosion characterizes the tree-covered slopes of the old, half-buried hills on which the dead trees still stand, stripped of their needles and of all value as conservators of the soil.*

FIGURE 8 – *The ash-covered 'window' in the lava flow representing the top of the old hill formed from a rafted fragment of the cone, still exposed in* 1948 *but covered over by the* 1950 *flows.*

FIGURE 9 – *A cave in the distinctive San Juan lava flow marks a spot where the liquid interior escaped to leave an arched opening in the flow as the hardened surface buckled and cracked open.*

FIGURE 10 – *Deeply buried but still living pine trees framing the surviving church façade in the San Juan lava flow in* 1948. *Within another year the trees gave up the struggle.*

time—only once when human observers were present—a great quantity of gas, with an accompanying rush of well-fluxed lava, would produce thin minor lava-streams from a cluster of such vents. The lava escaped in the form of a series of spectacular fountains which rose in solid columns 40 feet into the air.

The visitor who goes to Parícutin today, after its nearly eight years of progressively changing activity, will see a spectacle somewhat different from that which excited the early viewers. Those who have not been there before still find it the most thrilling experience of their lives: even in its senility it presents an impressive spectacle. The dust column now drifts out like chimney smoke, instead of rushing upwards and outwards in a five-mile tower of doom. Occasionally a great explosion will hurl numbers of bombs a mile from its base, but the few that usually accompany today's explosions roll harmlessly down its side, to collect around the base. The lava escapes quietly for the most part, flowing imperceptibly down from a vent which it has lifted some three hundred feet in the air. Only an occasional snort shows that it might yet do better things. Lava fountains have not been observed for over a year. The night view is lovely: incandescent fragments describe their graceful arcs through the sky, and from time to time are numerous enough to limn the cone in fire. Near the base the lava cascade glows as a sinuous ribbon, and a mile beyond, at the present lava front, a bright spot shines momentarily as a block falls out to expose a fresh face. The advance of the lava front is very slow.

It is difficult to predict what the future holds for Parícutin, or, at least, to predict when it will become quiescent. Probably its present activity gives the clue to its future behaviour. Certainly, the quantity of gas that has accompanied the emission of lava has diminished. The explosions are much milder and less frequent. From time to time the activity seems to stop entirely, now for only a few minutes at a time, but the interval could easily grow longer and longer. The rate of lava production fluctuates similarly, but in total it, too, appears to be diminishing. Everything points to a gradual running down of the activity, with, in the foreseeable future, a final cessation of all eruptions.

Book reviews

MEDIEVAL MINING AND ASSAYING

Bergwerk- und Probierbüchlein, *translated from the German by Anneliese Grünhaldt Sisco and Cyril Stanley Smith, with technical annotations and historical notes. Pp.* 196, *with illustrations. The American Institute of Mining and Metallurgical Engineers, New York.* 1949. $5 *net.*

This book, like the handsome translation of Biringuccio's *De la Pirotechnia* issued under the same auspices in 1942, has been published with the aid of the Seeley W. Mudd Memorial Fund. It is an English translation of two medieval booklets first printed early in the sixteenth century. The *Bergbüchlein*, or 'Little Book of Ores,' and the *Probierbüchlein*, or 'Little Book of Assaying,' were the first printed works dealing with aspects of mining and metallurgy respectively. As antecedents of the celebrated works of Biringuccio and Agricola they are of considerable historical interest, particularly as Agricola drew freely upon them in writing the classical *De Re Metallica*. The *Bergbüchlein* was intended as an introduction to mining geology for the use of beginners, whereas the *Probierbüchlein* was a collection of recipes and working directions for established artisans. Both books ran through many editions, and their complicated bibliography is discussed at some length with the help of many reproductions of the illustrated title-pages. The views of the *Bergbüchlein* on the generation of ores were purely alchemical, but there is much sound practical information on technical terms, tools, and the nature and associations of various ores. The *Probierbüchlein* is of an eminently practical nature, with accounts of such subjects as balances and weights, sampling, assay by touchstone, furnaces, crucibles, cupellation, assay of ores, and various methods of parting. The work of translation and editing has been accomplished admirably, there is a useful index, and the book is beautifully printed and produced.

JOHN READ

INTRODUCTION TO BIOLOGY

Biology, An Introduction to Medical and other Studies, *by P. D. F. Murray. Pp.* 600, *with numerous line drawings and half-tones. Macmillan and Company Limited, London.* 1950. 25*s. net.*

This long and very interesting book has been written for all students of biology, but especially for medical students, for whom the author has tried to provide a text which will correlate their first-year studies with those that follow.

This admirable intention is well maintained throughout the book. Beginning with unicellular animals and plants, the author takes us, in the course of 24 chapters, through the morphology of plants and animals,

emphasizing, by means of the ferns and the frog, the invasion of the land, and, by means of the flowering plants and the rabbit, the conquest of it. Chapters on man and the mammals complete this section and precede four chapters on the cell and vertebrate tissues, and nine on embryology and evolution. In this latter section the chapter on causal embryology, which describes important experiments and the conclusions to be drawn from them, is a useful lesson in experimental method applied to the problem of finding out how the complex adult animal develops.

The author's broad outlook is well expressed in the chapters on development, and in the ten chapters on growth, behaviour, and animal and plant physiology. The book ends with six concise chapters on fungi, bacteria, viruses, parasitic animals and plants, and symbiosis.

A valuable feature of the book is its wealth of excellent line and half-tone illustrations. Many of these are new and all are very well done. Some chapters, notably those on the vertebrate tissues, are given just those additional illustrations which communicate real understanding to the reader.

The style is clear and pleasant to read. This book is neither a dull statement of facts nor a book on elementary zoology mechanically shuffled into a book on elementary botany. It is botany and zoology integrated with one another, and with other branches of science, to make an attractively written, well-printed book which can be read with pleasure and understanding.

G. LAPAGE

COSMIC PHYSICS

Cosmical Electro-Dynamics, *by H. Alfvén. Pp.* 237, *with various line diagrams. Oxford University Press, London.* 1950. 25*s. net.*

The publication of Professor Alfvén's book coincides with great developments in cosmic physics, and is a most welcome and timely addition to the literature. The first chapters give excellent accounts of the motion of charged particles in magnetic fields, and of the fundamental features of electric discharges in gases, with particular reference to the conditions in interstellar space. In 1942 Alfvén postulated the existence of a new type of wave arising when hydrodynamic motion occurs in an electrically conducting medium situated in a magnetic field. The chapter devoted to these magneto-hydrodynamic waves is of great value and interest. The chapter on solar physics occupies nearly one-third of the book, and Alfvén seeks to explain many solar phenomena such as sunspots, prominences, and the high temperature of the corona, in terms of the magneto-hydrodynamic theory. The fundamental requirement for the success of these theories is that the sun possesses a general magnetic field. It is unfortunate that in the short time since the book was written opinion has markedly hardened against the existence of such a general solar field. Nevertheless, the chapter contains a wealth of data about solar conditions, and is of the utmost value. The last two chapters are devoted to magnetic storms and aurorae, and the origin of cosmic rays. These are perhaps the least successful part of the book, owing to the severe restriction of treatment. The aurora is treated as an electric field effect, and the cosmic ray energies are considered to arise by acceleration in the fields due to a double star generator. Although these explanations are perfectly plausible, the book would have gained in value from a further treatment of the alternative views which are currently held.

A. C. B. LOVELL

ORGANIC REACTIONS

Organic Reactions. Volume V. *Editor-in-Chief, Roger Adams. Pp. viii* + 446. *John Wiley and Sons, New York; Chapman and Hall Limited, London.* 1949. 48*s. net.*

Organic Reactions is now a standard work of reference. It furnishes a wealth of information about many organic reactions, with regard both to the practical details of their application and to the various compounds to which they have been applied.

Volume V deals with the following topics: the synthesis of acetylenes; cyanoethylation, involving the addition reactions of acrylonitrile; the Diels-Alder reaction as applied to quinones and unsaturated ketones; the Schiemann reaction for the preparation of aromatic fluorine compounds from diazonium fluoborates; the Friedel-Crafts type reaction with aliphatic dibasic acid anhydrides; the Gattermann-Koch reaction; the Leuckhart reaction, the reductive alkylation of amino compounds by aldehydes and ketones; oxidation by means of selenium dioxide; the Hoesch ketone synthesis; and the Darzens glycidic ester condensation, i.e. the production of an αβ-epoxy ester from a carbonyl compound and an α-halogen ester.

The reviewer ventures to suggest that, as the separate chapters are written by experts, they might on occasion add to the value of their articles by going beyond a statement of the scope of the reaction and the cataloguing of its applications. Perhaps a little more space might be devoted to discussions of reaction mechanisms, and opinions as to further applications of the reactions would be welcome. The usefulness of these reactions may be taken for granted; improvements are likely to result only from an appreciation of their limitations. The very high standard of the articles in previous volumes is maintained in Volume V.

W. BAKER

AMINO ACIDS AND PROTEINS

Amino Acids and Proteins—Cold Spring Harbor Symposia on Quantitative Biology. *Pp.* 217, *with numerous half-tone and line illustrations. The Biological Laboratory, Cold Spring Harbor, U.S.A.* 1950. $7 *net.*

This report of the symposium maintains the tradition of its well-known predecessors, which is to put on record for those interested in the various aspects of a particular field of investigation a series of authoritative summaries of the latest work. The chapters are not arranged in a logical sequence, but the field is nevertheless well covered. Amino acids are considered from the point of view of their analysis by chromatographic and isotope dilution methods, and of their biosynthesis and metabolism. Articles also deal with the rapidly expanding subject of the metabolism and synthesis of peptides, and with the application of counter-current techniques for their separation and as a test of homogeneity. Just over half the chapters, however, are concerned with the fantastically complicated problems posed by the intact proteins. These include their chemical reactions, physical properties, methods of fractionation, and, of course, hydrolysis. Further reviews cover the problems of protein structure with special reference to insulin, that great friend of man which is surely going to be the first protein to be graced with something like a structural formula. The book has many examples illustrating the American genius for lucid illustration, and altogether it makes exciting reading out of a subject so easily made to appear dull and uninteresting. G. E. DENT

Some books received

(*Note.* Mention of a book on this page does not preclude subsequent review.)

AGRICULTURE

D.D.T. and Newer Persistent Insecticides (*2nd edition*), *by T. F. West and G. A. Campbell. Pp.* 632, *with* 13 *half-tone plates. Chapman and Hall Limited, London.* 1950. 50*s. net.*

BIOLOGY

The Actinomycetes, *by Selman A. Waksman. Pp.* 230, *with various line and half-tone illustrations. The Chronica Botanica Co., Waltham, Mass.; Wm. Dawson and Sons Limited, London.* 1950. $5 *net.*

Man is a Microcosm, *by J. A. V. Butler. Pp.* 151, *with various line and half-tone illustrations. Macmillan and Company Limited, London.* 1950. 10*s.* 6*d. net.*

New Biology—No. 9. *Pp.* 128, *with various half-tone illustrations. Penguin Books, Harmondsworth.* 1950. 1*s.* 6*d. net.*

Principles of Human Genetics, *by Curt Stern. Pp.* 617, *with line and half-tone illustrations. W. H. Freeman and Company, San Francisco, California.* 1949. 41*s. net.*

BIOGRAPHY

Jan Ingenhousz, Plant Pathologist, *by Howard S. Reed. Pp.* 396, *with several half-tone illustrations. Chronica Botanica Co., Waltham, Mass.; Wm. Dawson and Sons Limited, London.* 1950. $3 *net.*

BOTANY

Die Chromosomenzahlen der Gefässpflanzen Mitteleuropas, *by George Tischler. Pp.* 256. *Dr W. Junk, The Hague.* 1950. *Fl.* 42.50 *net.*

CHEMISTRY

Analytical Absorption Spectroscopy, *edited by M. G. Mellon. Pp.* 618, *with numerous half-tone and line illustrations. John Wiley and Sons, New York; Chapman and Hall Limited, London.* 1950. 72*s. net.*

Chemical Society—Annual Reports, 1949 (Volume 46). *Pp.* 333, *with line diagrams. The Chemical Society, London.* 1950. 25*s. net.*

College Chemistry, *by Linus Pauling. Pp.* 705, *with various line drawings and charts. W. H. Freeman and Company, San Francisco, California.* 1950. 34*s. net.*

Physical Aspects of Organic Chemistry, *by W. A. Waters. Pp.* 539, *with various line diagrams. Routledge and Kegan Paul Limited, London.* 1950. 35*s. net.*

Principles of Ionic Organic Reactions, *by Elliot R. Alexander. Pp.* 318. *John Wiley and Sons, New York; Chapman and Hall Limited, London.* 1950. 44*s. net.*

Principles of Nuclear Chemistry, *by Russell R. Williams, Jr. Pp.* 307, *with numerous line diagrams. Van Nostrand Company Inc., New York; Macmillan and Company Limited, London.* 1950. 28*s.* 6*d. net.*

Quantitative Ultramicroanalysis, *by Paul L. Kirk. Pp.* 310, *with line diagrams. Chapman and Hall Limited, London.* 1950. 40*s. net.*

GENERAL SCIENCE

The British Journal for the Philosophy of Science. *British Philosophical Society* (*Vol. I, No.* 2). *Pp.* 172. *Thomas Nelson and Sons Limited, Edinburgh.* 1950. 7*s.* 6*d. net.*

An Introduction to Laboratory Technique (*Second edition*), *by A. J. Ansley. Pp.* 288, *with various line drawings and half-tone illustrations. Macmillan and Company Limited, London.* 1950. 16*s. net.*

Science News No. 17, *edited by J. L. Cramer. Pp.* 156, *with numerous half-tone and line illustrations. Penguin Books, Harmondsworth.* 1950. 1*s.* 6*d. net.*

The Science of Humanity, *by K. G. Collier. Pp.* 339. *Thomas Nelson and Sons Limited, Edinburgh.* 1950. 12*s.* 6*d. net.*

The Scientist's Ready Reckoner, *by W. Roman. Pp.* 142. *Dr W. Junk, The Hague.* 1950. *Fl.* 6.50 *net.*

GEOCHEMISTRY

Geochemistry, *by Kalervo Rankama and Th. G. Sahama. Pp.* 911. *University of Chicago Press, Chicago; Cambridge University Press, London.* 1950. £5 12*s.* 6*d. net.*

INDUSTRY

Progress in Coal Science, *by D. H. Bangham. Pp.* 456, *with half-tone and line illustrations. Butterworth's Scientific Publications Limited, London.* 1950. 40*s. net.*

The Science of Petroleum (Vol. V, Part I)—Crude Oils. *General editors, Benjamin T. Brooks and A. E. Dunstan. Pp.* 200, *with various half-tones and line diagrams. Oxford University Press, London.* 1950. 48*s. net.*

MEDICINE

The Design of Toxicity Tests, *by W. L. M. Perry. Pp.* 51, *with several line diagrams. His Majesty's Stationery Office, London.* 1950. 1*s.* 6*d. net.*

Documenta Ophthalmologica, *edited by F. P. Fischer, A. J. Schaeffer, and Arnold Scorsby. Pp.* 362, *with various line diagrams. Dr W. Junk, The Hague.* 1950. *Fl.* 36; £3 7*s.* 11*d. net.*

PHYSICS

Elements of Heat Transfer and Insulation, *by Max Jacob and George A. Hawkins. Pp.* 230, *with numerous line diagrams. John Wiley and Sons, New York; Chapman and Hall Limited, London.* 1950. 32*s. net.*

The Flight of Thunderbolts, *by B. F. J. Schonland. Pp.* 152, *with various half-tone and line illustrations. Oxford University Press, London.* 1950. 15*s. net.*

Interaction entre le Noyau et son Cortège Electronique—*Réunions d'études et de mises au point tenues sous la présidence de Louis de Broglie. Pp.* 198, *with line drawings. Editions de la Revue d'Optique Théorique et Instrumentale, Paris.* 1949. 18*s. net.*

Ionization Chambers and Counters, *by D. H. Wilkinson. Pp.* 266, *with numerous line diagrams. Cambridge University Press, London.* 1950. 25*s. net.*

New Atoms, *by Otto Hahn. Pp.* 183. *Elsevier Publishing Company, Amsterdam; Cleaver-Hume Press Limited, London.* 1950. 12*s.* 6*d. net.*

Practical Spectroscopy, *by George R. Harrison, Richard C. Lord, and John R. Loofbourow. Pp.* 605, *with numerous half-tones and line diagrams. Blackie and Son Limited, London and Glasgow.* 1950. 35*s. net.*

Verständliche Elemente der Wellenmechanik, *by Karl Jellinek. Pp.* 304, *with various line diagrams. Wepf and Co., Basle.* 1950. *S. Fr.* 34 *net.*

Wave Theory of Aberrations, *by H. H. Hopkins. Pp.* 167, *with numerous line diagrams. Oxford University Press, London.* 1950. 15*s. net.*

Weltsystem, Weltäther und Die Relativitätstheorie, *by Karl Jellinek. Pp.* 450, *with several line diagrams. Wepf and Co., Basle.* 1950. *S. Fr.* 45 *net.*

Notes on contributors

H. GODWIN,
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Born 1901. Educated at Long Eaton County School, Derbyshire, and Clare College, Cambridge. Made a fellow of Clare College, Cambridge, in 1926, and is now demonstrator and lecturer in botany in the University of Cambridge. Began research in plant physiology under F. F. Blackman in 1922, but turned progressively to ecological research, especially upon the vegetation of fens and peat-bogs.

In 1930 he began research, jointly with his wife, Margaret E. Godwin, upon pollen analysis in relation to ecological and historical aspects of vegetation. Work with the Fenland Research Committee led to publication of numerous papers upon the geological and vegetational history of the East Anglian Fenland; subsequently research has been published on the evidence given by pollen analyses of relative movements of land and sea level, and upon the general outline of vegetational history of Britain.

In 1948 Dr Godwin was made head of the Cambridge University sub-department of Quaternary Research. He is honorary editor of the *Journal of Ecology* and since 1932 has been co-editor of the *New Phytologist*.

A. G. GAYDON,
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Born in London in 1911. Educated at Kingston Grammar School and Imperial College, London (1929–34). From 1934–6 he was on the research staff of the British Cotton Industry Research Association. Since 1937 he has been engaged in research at Imperial College on molecular spectra and applications of spectroscopy in combustion. He has held various research fellowships, including a Radiation Research Fellowship and Leverhulme Research Fellowship. Present appointment is as Warren Research Fellow of the Royal Society.

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Was born in Lancashire in 1899 and was educated at Repton School and at Gonville and Caius College, Cambridge, and St Thomas's Hospital, London. In 1926 he was appointed lecturer and subsequently reader in medical entomology at the London School of Hygiene and Tropical Medicine. His research has been mainly concerned with the physiology of insects. In 1943 he was appointed director of a unit of insect physiology under the Agricultural Research Council, and since 1945 has combined this post with that of reader in entomology at Cambridge University.

R. M. CALMAN,
M.B.,

Was born in London in 1917 and was educated at St Paul's School and Glasgow University. From 1942 to 1944 was assistant to the professor of bacteriology in that university. Was pathologist in the Royal Air Force Volunteer Reserve from 1945 to 1947, and then returned to Glasgow University as assistant until he took his present appointment as bacteriologist and assistant director of the Bernhard Baron Memorial Research Laboratories, Queen Charlotte's Maternity Hospital, London, where he has made serological studies of streptococci and staphylococci.

JOHN MURRAY,
M.A., M.D.,

Was born in 1910 and was educated at Malvern College and Emmanuel College, Cambridge, and became assistant pathologist at the Middlesex Hospital in 1939. During the last war was lecturer in Middlesex Hospital Medical School and pathologist in the Emergency Medical Service. Has worked on the Rhesus factor since 1941. His other studies have included the 'crush syndrome' and the bacteriology of war wounds. Since 1947 he has been director of the Bernhard Baron Memorial Research Laboratories, Queen Charlotte's Maternity Hospital, London.

ANN R. SANDERSON,
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A pupil of the Morgan Academy, Dundee. Is a graduate of the University of St Andrews and is now a lecturer in zoology in University College, Dundee (University of St Andrews). From 1939 to 1941 was a Research Fellow in the Women's College, University of Sydney, investigating the biology and cytology of certain parthenogenetic insects.

DAVID W. HALL,
B.Sc., F.R.E.S.,

Was born in 1924 and was educated at Alloa Academy. He is a graduate of the University of St Andrews. A colleague of Dr A. R. Sanderson, he is an assistant lecturer in University College, Dundee. He has a wide knowledge of insect pests in stored food products, and is now an honorary inspector with the Department of Agriculture for Scotland.

E. GLUECKAUF,
Dr.-Ing., M.Sc., D.I.C.,

Was born in 1906 and studied chemistry at the University and at the *Technische Hochschule*, Berlin. He subsequently did research in the laboratory of F. A. Paneth, first at Imperial College, London, and then at Durham. He was a Mackinnon Research Student of the Royal Society from 1942 to 1944. In 1947 he joined the Atomic Energy Research Establishment at Harwell, where he built up a large physical chemistry group. His main contributions to chemistry are scientific papers on the theory of chromatography and ion exchange, on micro-constituents of the atmosphere, and on specialized fields of radio-activity.

D. McKIE,
Ph.D., D.Sc.,

Was born in Monmouthshire in 1896. He entered University College, London, in 1920 and carried out research under Professor W. E. Garner on the heats of adsorption of gases by charcoal. Later he turned from physical chemistry to the history of chemistry, and is now reader in the History of Science in the University of London.

FREDERICK H. POUGH,
S.B., M.S., Ph.D.,

Was born in 1906, and was educated at Washington University, Harvard University, and the Victor Goldschmidt Institute at Heidelberg. He first came to the American Museum of Natural History in 1935, and since 1945 he has been curator of physical geology and mineralogy. He is one of the pioneer workers on the irradiation of gem stones with modern sources (cyclotrons, atomic piles). He has made numerous trips to the new volcano in Mexico, Paricutin, and, in the course of his studies, has compiled a motion-picture record of its history which has been shown in many parts of the world.

ENDEAVOUR

The British quarterly scientific review ENDEAVOUR was first published in January 1942. Its purpose was to enable men of science, and particularly British men of science, to speak to the world in an hour when not only nations but the internationalism of science were suffering the dangers of warfare. For the better fulfilment of this purpose ENDEAVOUR was from the first published in four separate editions—English, French, Spanish, and German. An Italian edition has been published since January 1948. Today the situation is happily different, but there can be no lasting peace without full and sincere co-operation between nations in every realm of human enterprise. In the scientific field ENDEAVOUR can thus play as useful a part in peace as it did in war, and for this reason the decision has been taken to make its publication permanent.

ENDEAVOUR is distributed without charge to senior scientists, scientific institutions, and libraries throughout the world, the guiding principle being that of helping scientists overseas to maintain those contacts which their British colleagues have always so much valued. Within these limits the Editors are at all times glad to consider the addition of new names to the mailing list.

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